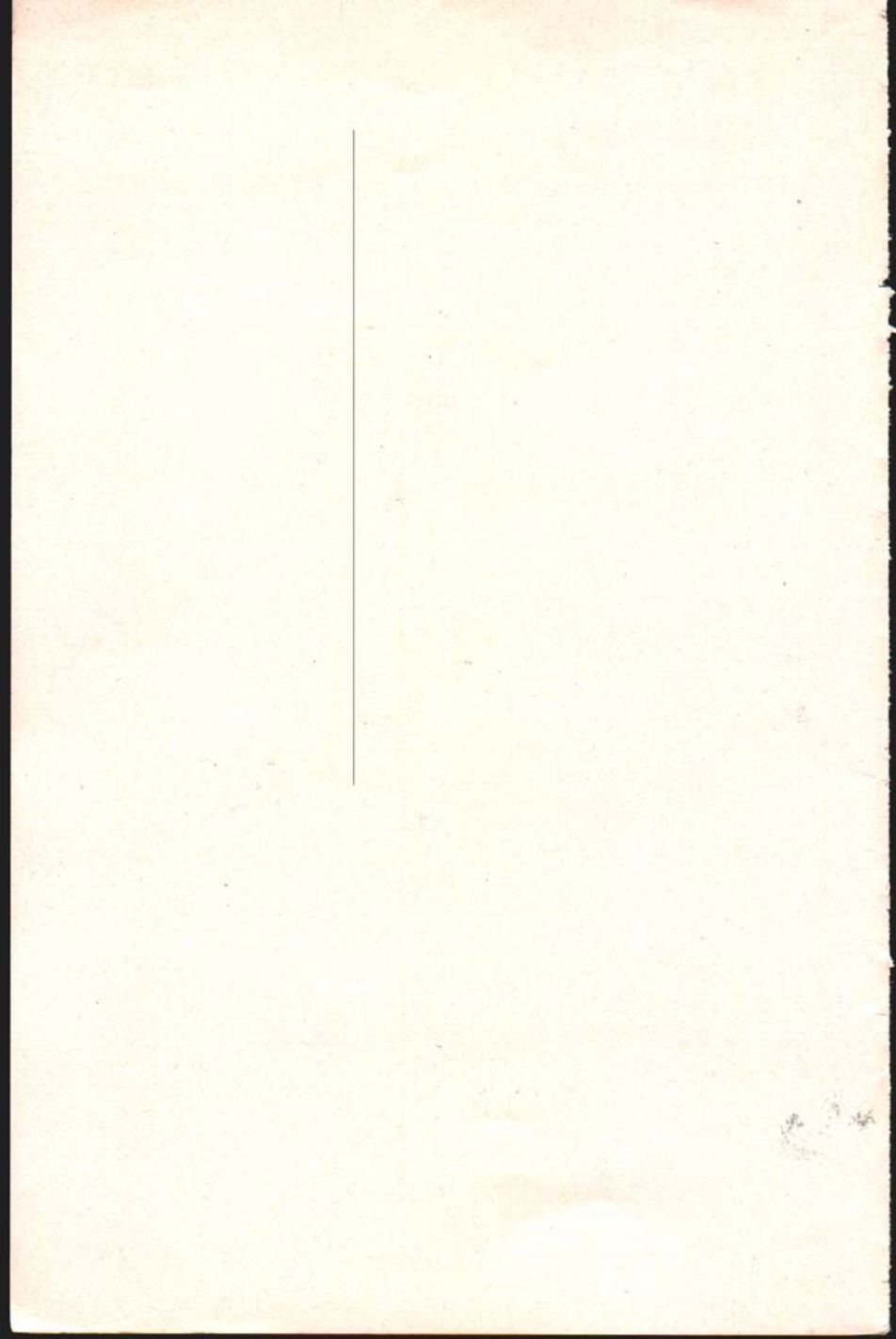


Commercial Strawberry Production in Michigan

Culture, Insects, and Diseases



MICHIGAN STATE UNIVERSITY
Cooperative Extension Service • East Lansing



COMMERCIAL STRAWBERRY PRODUCTION IN MICHIGAN

Culture, Insects, and Diseases

Extension Bulletin 356

*By Harry K. Bell, Jerry H. Mandigo, R. F. Carlson,
Ray Hutson, and R. H. Fulton*

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Commercial Strawberry Production in Michigan

I. CULTURE

By HARRY K. BELL, JERRY H. MANDIGO
and R. F. CARLSON¹

The most important small fruit crop in Michigan is the strawberry, grown either commercially or in home gardens in every county in the State. Climate and soil are generally ideal to produce high quality fruit. Large cities provide ready markets for Michigan strawberries, and processors annually absorb a large volume of the crop each year.

Michigan has been a leading center of strawberry production in the United States for many years. Only the states on the Pacific Coast—California, Oregon, and Washington—produce more strawberries than Michigan. In addition to the fruit, sales of strawberry plants by Michigan nurserymen each year total thousands of dollars.

For many years most of Michigan's commercial strawberries were grown in the southern half of the Lower Peninsula, mainly in southwestern counties, but during recent years, acreage has increased greatly in northern parts of the State. Only 10 years ago, less than 500 acres of strawberries were grown north of a line from Muskegon to Bay City. Now over 2,000 acres are devoted to the crop there. In the Upper Peninsula, the Hancock-Houghton area has about 500 acres in strawberries. There the crop matures in mid-July, after most fresh strawberries from other areas are off the market. Due to this late season, prices paid to Upper Peninsula growers average higher than in most other areas of the state.

Many Michigan farmers have discovered how well strawberries fit in with their other crops. Such diversity reduces the risks found in one-crop enterprises such as sour cherry production. Profits are possible with both small family-sized plantings or large commercial operations of 50 acres or more.

The strawberry is popular in gardens because it is easy to grow. Ample fruit can be produced on small areas of land cared for by members of the family. Pest control usually is not needed to get fair yields

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TABLE 1—Production, value, and utilization of the Michigan strawberry crop for the seasons 1948 through 1957*

Crop year	Processing berries		Fresh berries	
	Quantity (1,000 pounds)†	Price/lb. paid to growers (cents)	Quantity (1,000 pounds)	Price/lb. paid to growers (cents)
1948.....	7,310	21.0	21,348	25.8
1949.....	3,298	14.4	19,958	22.2
1950.....	19,584	18.1	16,704	19.6
1951.....	10,608	16.8	22,872	17.8
1952.....	13,260	14.9	22,380	17.5
1953.....	13,770	18.5	18,990	19.4
1954.....	9,180	20.6	14,256	22.8
1955.....	11,050	19.1	21,998	22.5
1956.....	15,400	14.8	18,200	18.1
1957.....	11,000	10.5	30,760	16.0

*Data of the Agricultural Marketing Service, U. S. Department of Agriculture, December 1957.

†A quart box of strawberries weighs about 1½ pounds, and a 16-quart crate weighs about 24 pounds.

of fruit from small plots. Strawberries ripen early in the year, when other homegrown fresh fruits are not available. If the fruit is sold locally, you can receive a fairly high income from a small area. If grown only for home use, you can process the surplus into jam or freeze for use later in the year.

PRODUCTION AND VALUE OF THE CROP

Over 10,000 acres of strawberries are harvested in Michigan each year, bringing in around \$6,000,000 to growers. Although the state-wide average yield is only 3,000 to 4,000² pounds per acre, this is much less than many growers harvest. In some plantings, 6,000 to 7,000 pounds of berries per acre are grown yearly, and in best years the harvest may reach 10,000 pounds or more.

Prices paid to growers for strawberries vary depending on size of the crop in Michigan and competing States, variety and quality of the fruit, and the type of market. Average prices paid during recent years are listed in Table 1.

Strawberries are favorites and can be served many ways: eaten fresh or frozen for dessert and breakfast, made into preserves, jams, jellies, and ice cream toppings, and added to cake, pie, and ice cream.

Strawberries are the most popular of all frozen fruits. While valued mainly for their flavor, they are a good source of vitamin C,

²A 16-quart crate contains about 24 pounds of strawberries.

TABLE 2—Average costs of productions for five strawberry growers in southwestern Michigan based on 1956 prices

First year cost per acre up to picking time (2nd Year):	1 acre
Plants @ \$10.00 per M. 7,000 plants per acre.....	\$ 70.00
Planting at rate of 22,000 per 10 hour day.....	14.00
Hand hoeing.....	22.50
Pinching blossoms.....	7.50
Power hoeing and late season cultivation (\$6.60 per acre).....	66.00
Spraying cost.....	33.40
Fertilizer at 1,000 lb. per acre.....	34.00
Sidedress with starter solution, \$4.00 labor; \$4.00 materials.....	8.00
Preparing of ground for planting.....	12.00
Machine mulching.....	9.00
1½ tons straw at \$20.00 per ton.....	30.00
Fall application of chemical weed spray, \$7.30 materials; \$3.00 labor.....	10.30
Hand weeding previous to picking.....	12.00
Irrigation.....	40.00
Frost prevention.....	15.00
Total first year production costs.....	\$383.70
Cost from first year harvest up to second year harvest:	
Post-picking rototilling @ \$8.00 per acre.....	\$ 8.00
Cultivation (2 times) @ \$7.00 per acre.....	14.00
Post-picking hoeing.....	36.00
Early and late fertilizers.....	18.00
Mulching (total cost).....	39.00
Frost prevention (20 hours).....	15.00
Irrigation average of 3 acre inches per year @ \$10.00.....	30.00
Spraying.....	25.00
Total second year production costs.....	\$185.00

with most varieties containing as much as orange juice. They also contain small amounts of vitamin A and thiamin.

DURATION OF PLANTINGS AND COSTS

Strawberry plantings in Michigan usually are kept for 2 and sometimes 3 or more harvest seasons. Normally the first crop is larger than the later crops. After the second fruiting year, yields are often low and berries small due to weeds, diseases and insects.

Strawberry production costs are hard to appraise due to differences among growers. Cost estimates from several good strawberry farms in southwestern Michigan are summarized in Table 2. While they vary somewhat from farm to farm, these figures represent fairly recent costs. Use them for comparison with your operation. Since production costs per acre are high for strawberries, compared with many

TABLE 3—Effect of yields on costs of producing strawberries

Item	Cost/qt. (cents)	Cost/lb. (cents)
First Year Production Costs		
140 crates* (3,080 lbs. †) per acre.....	17.2	12.4
200 crates (4,400 lbs.) per acre.....	11.9	8.7
400 crates (8,800 lbs.) per acre.....	5.9	4.4
Second Year Production Costs		
140 crates.....	8.3	6.0
200 crates.....	5.7	4.2
400 crates.....	2.8	2.1
Overhead Costs (land, machinery, buildings, etc.).....	2.5	2.0
Harvest Costs		
Picking.....	6.0	7.0‡
Packing and supervision.....	1.0	.5
Crates and cups.....	4.4
Total Harvest Cost.....	11.4	7.5

*16-quart crates.

†After stems have been removed, a quart box of strawberries weighs about 22 ounces; a 16-quart crate, thus would weigh about 22 pounds and 140 crates x 22 pounds = 3,080 pounds.

‡Includes cost of capping.

other crops, good yields are needed to make worthwhile profits. The effect of yield per acre on production costs per unit is shown in Table 3.

IMPORTANT COMMERCIAL PRODUCTION AREAS

Berrien and Van Buren counties (see Fig. 1) together grow about one-third of the Michigan strawberry crop. Other important counties include Allegan, Cass, and Kalamazoo in southwestern Michigan; Ottawa, Muskegon, Kent, Oceana, Ionia, and Mason in central western; Manistee, Leelanau, and Grand Traverse in northwestern; Alpena in northeastern; near Portage Lake in Houghton county; and scattered areas in many other counties.

About a third of the State's strawberries are sold at the Benton Harbor cash market in Berrien county (Fig. 2). Most of these go to fresh retail markets in Chicago, Detroit, Cleveland, Cincinnati, Pittsburgh, St. Louis and sometimes as far as the Eastern Seaboard. Smaller fresh market areas are near Grand Rapids, Alpena, Houghton, Detroit, Flint, Lansing, Saginaw, Manistee, Traverse City, and several other cities.



Fig. 2. View of the Benton Harbor cash market, where about one-third of the Michigan crop of strawberries is sold each year.

Usually about two-thirds of the total crop is sold for fresh use, and the rest for processing. Most of the processing crop is grown in southwestern and northwestern Michigan.

VARIETIES

General

Several thousand varieties of strawberries have been named over the years. New ones are listed each year, but many are soon discarded due to various faults. Most varieties are not widely adapted and do best in or near regions where they were developed. None of the good varieties of Southern and Western States grow well in Michigan.

The main varieties in Michigan are "old timers"—those that have stood the test of time. Two of these, Robinson and Premier, make up 90 percent of the State's strawberry acreage. The other 10 percent consist mainly of older varieties too. About 60 percent of the acreage is Robinson, introduced in 1932; 30 percent is Premier (1912); and about 5 percent is Dunlap (1890), Catskill (1933), and Sparkle (1942).

Growers find it best to include only 2 or 3 varieties in the main planting each year, using those with good past records in the area. Test new varieties on a small basis for 2 or 3 years to find their merits or faults. Remember that most markets are slow to accept new varieties.

Consider the type of market when choosing strawberry varieties. Berries for distant markets must be fairly firm, bright red, large, and

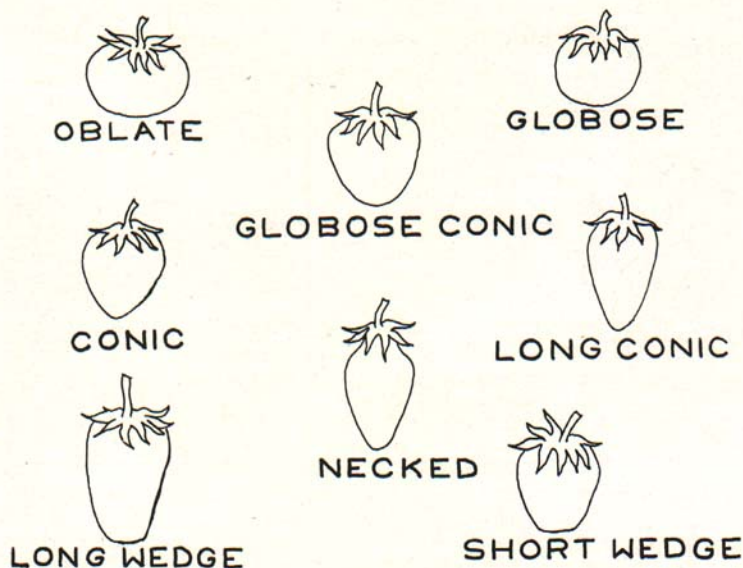


Fig. 3. Different shapes of strawberry fruits. Berries which are "necked" like the Catskill variety are easy to "cap".

uniform in size and shape. For nearby markets, flavor and quality often are more important than firmness. Commercial processing needs uniform size and bright red outer and inner color. Easy removal of stems (called "capping") also is important for processing varieties. Those which cap most easily are "necked" at the stem end of the berry, like Catskill (Fig. 3). Such berries are easy to pick, leaving the stems on the plants. (Fig. 4).

Common Standard Varieties

Robinson (Scarlet Beauty; Kardinal King; Neet) Early Mid-season

Robinson is the leading variety in Michigan and brings top fresh market prices. It is not a good processing variety. Its plants are medium in size, but they grow many runners (Fig. 5), some forming late in the season, crowding better plants set earlier.

Robinson grows well on light soils where other varieties may fail. Because of this, it is known as a "sandy soil" variety but it does well



Fig. 4. Two eight-quart carriers of Catskill berries from a field in Leelanau County. Destined for a nearby processing plant, note that they have been picked without "caps". Mexican-American migrant workers harvest much of the crop there. After the strawberry harvest, they then will help with the cherry harvest in nearby orchards.



Fig. 5. Two center rows are Robinson strawberries trained to the matted row system. This variety is an excellent plant-maker and usually makes a good full row as seen here.



Fig. 6. Six-quart carrier of Robinson berries. The large size and bright red, lustrous appearance of this variety give it excellent eye appeal. Note the ridges in the berries — typical of the larger fruits in the early pickings of this variety.

on most soils. It is the most productive variety in the areas of Michigan where it is adapted, ripening a few days after Premier.

The large, bright, glossy red berries (Fig. 6) are not very firm, but they ship fairly well, except in hot, wet seasons. Their flavor and quality are only fair. Most berries have pale red to white flesh, often with hollow centers. **Robinson** is very prone to injury from leaf blight and stem end fruit rot.

Premier (Howard 17). Early.

Premier is the second most important variety in Michigan. **Virus-free Premier** or **U.S.D.A. Premier** actually is another variety (see discussion of **U.S.D.A. Premier** below).

Premier is a good variety for nearby fresh markets and for commercial processing. It grows well on loams and heavier soils in most parts of the state. The blossoms are more resistant to frost than most varieties. The first berries are fairly large, but in later pickings they are quite small. The primary ("king") blossoms often yield double or split berries. The fruit is medium red, fair in quality and flavor, soft in texture.

U.S.D.A. Premier (Virus-free Premier). Early.

This is a distinct variety in itself, though similar to standard **Premier** in some respects: (1) fruit size and shape are the same; (2)

primary berries often are double; and (3) their blossoms are tolerant to frost.

U.S.D.A. Premier differs from standard **Premier** in these respects: (1) leaves are lighter green; (2) plants are smaller and grow more like **Robinson**, with many runners often forming late in the season; (3) it grows well on sandy soils; (4) each crown usually grows only one upright blossom stalk like **Robinson**; (5) the fruit ripens 2 or 3 days later than **Premier**; (6) it is lighter red; (7) it is more acid; and (8) it is "mushier" and less attractive in frozen packs when thawed.

Catskill. Early mid-season.

Catskill does best in northern Michigan near Grand Traverse Bay. It is a good variety for nearby fresh markets and commercial processing. Virus-free plants are vigorous and productive, their berries large, fairly soft, bright red, with good flavor and quality, and cap easily. Most of the crop is sold to processors.

Dunlap (Senator Dunlap; Senator). Early mid-season.

Dunlap grows well on heavier soils in most of Michigan. It is a fair variety for local fresh markets and home gardens. Plants can withstand both drought and low temperature. Berries are deep red, soft, and medium to small.

Dorsett. Early mid-season.

Dorsett is a good variety for gardens and commercial processing. Virus-free plants are vigorous and productive. Berries are bright red, fairly soft, large, and of good quality.

Tennessee Beauty. Late mid-season.

Tennessee Beauty produces well in southern Michigan. It is a good processing variety. Berries are bright red, firm, tart, small to medium, and cap easily.

Newer Varieties (for trial only)

Armore. Late.

Armore is a good fresh market shipping variety. Berries are bright cherry red, glossy, firm, and large. Foliage is subject to mildew damage.

Empire. Early mid-season.

Empire is a fair variety for most uses. Virus-free plants are vigorous and productive with blossoms tolerant to frost. Berries are large, bright red, fairly soft, and of good quality.

Erie. Late.

Erie is a good variety for local fresh market and home gardens. Berries are large, fairly dark, fairly firm, and of fair quality.

Essex. Very early.

Essex is a good variety for very early home garden use. It ripens almost a week before **Premier**. Berries are small, but very high in quality.

Jerseybelle. Late.

Jerseybelle is a fresh market and home garden variety. Plants are large, forming less runners than most varieties but enough for a well-spaced matted row. Berries are firm, of good flavor, and deep red. They have large bright green caps and large yellow seeds protruding above the skin.

Jumbo. Mid-season.

Jumbo is a fair variety for home garden and commercial processing. The berries are large at first but medium to small later; fairly firm; medium to dark red; and many are rough and irregular in shape.

Pocahontas. Early mid-season.

Pocahontas, a new all-purpose variety, is vigorous and very productive. Berries are fairly firm, tart, glossy, light red, and medium to large in Michigan.

Earlidawn. Very early.

Earlidawn is a promising new all-purpose variety which ripens 2 or 3 days earlier than **Premier**. Berries are large, bright red, fairly firm, and tart.

Varieties Resistant to Red Stele³

Strains of the red stele fungus occur in some Michigan strawberry fields. Only red stele-resistant varieties will grow well on

³See section III, "Strawberry Diseases".

infested land. The fungus stays on in the soil, and there is no known treatment to destroy it. Some of the more common red stele-resistant varieties are:

Fairland. Early mid-season.

Fairland grows well in southern Michigan. Its plants are vigorous and usually productive. Berries are medium to large, deep red, and fairly soft.

Sparkle (Paymaster). Mid-season.

Sparkle, the best red stele-resistant variety grown in Michigan, does well all over the state. It is productive, vigorous, and runners freely. Berries are medium to small, glossy, medium to dark red, and fairly firm with very high quality.

Vermilion. Early mid-season.

Vermilion has been fairly productive in Michigan trials. Berries are fairly firm, medium red, and small to medium. Try **Vermilion** only on red stele-infested soils where **Sparkle** and **Fairland** have not grown well.

Aberdeen, **Redcrop**, **Temple**, and **Plentiful** are other red stele-resistant varieties which have not produced well in Michigan trials. **Redglow** and **Surecrop** are two new red stele-resistant varieties which have shown good promise in southern Michigan trials. **Redglow** ripens with **Premier**; **Surecrop** with **Fairland**. Both have rated well for fresh use and frozen packs.

Everbearing Varieties

Most everbearing varieties of strawberries have two crops each year: (1) Late spring or early summer; and (2) from mid-summer to the first killing frost in the fall.

Everbearing strawberries are not successful in large commercial plantings for several reasons: (1) Plants often are low in vigor and production during hot weather; (2) much handwork is needed to get good yields; and (3) fruit quality is low during hot weather. If grown well, they are a fair fruit for home gardens. Market gardeners near cities and resort areas often make fair profits with everbearing varieties.



Fig. 7. Everbearing strawberries trained to a double row hill system.

The best training system for most everbearers is in hills (Fig. 7). Set the mother plants 12 to 15 inches apart in double or triple rows, and remove runners as they appear. Some varieties make runners freely and perform fairly well, using a spaced runner system.

Some of the more common everbearing strawberry varieties grown in Michigan are:

Twentieth Century.

Its plants are vigorous, but make few runners. Fruit is light red, quite large, irregular, fairly firm, and of good quality and flavor.

Gem, Superfection, and Brilliant.

These varieties are all very much alike. The plants grow many runners, which is unusual with everbearers. Berries are light red, of medium size, soft and very acid in warm weather, but sweeter and firmer in cooler weather.

Red Rich.

Red Rich plants are very vigorous, but grow few runners. Berries are dark red, medium in size, and of good quality.

Department of Horticulture Breeding Program

The Department of Horticulture of the Michigan Agricultural Experiment Station started a strawberry breeding program a few years ago. Its main objectives are to produce new better varieties of strawberries adapted to Michigan. Berries suitable for either fresh market or processing are being sought in this program. The first selections were sent to some Michigan growers for field testing in the



Fig. 8. Plantation of Premier on a contour-terraced slope of sandy type soil. Such sites, while excellent for strawberries, need sound management practices like this.

spring of 1954. It will take several years of testing before the first varieties from this program can be introduced.

ESTABLISHING THE PLANTING

Site and Soil

Choose sites for strawberries which have enough slope to permit good air and water drainage. Contours or terraces on slopes of 5 percent or more will reduce soil erosion (Fig. 8).

Low flat lands next to streams or small inland lakes usually are frosty for cold air drains into such places, and frost injury to blossoms is likely to occur often. Bottom lands, however, are usually fertile and moist, and strawberries grow well there. You can protect blossoms on these sites with sprinkler irrigation systems (see section on "Spring Frost Protection").

Varieties on southern slopes often ripen a few days earlier than berries on northern slopes or on bottom lands. Plant late and ever-bearing varieties on northern slopes and bottom lands since such sites are cooler, more moist, and usually more productive.

Strawberries grow well on many soil types. They grow best on well drained loams, or sandy loams, with porous subsoils that hold moisture well. Sandy soils are good under irrigation and with ample fertilizer. Such soils are easy to manage since they drain fast after

rains, while clayey soils compact if worked too soon after rain and may harden and crack during hot, dry weather. Clayey soils often are too wet for early spring planting of strawberries. Avoid muck and peat soils for strawberries. Plants make very vigorous growth on these soils, but the fruit is usually soft and low in quality. Mucks and peats also are low and subject to late spring frosts.

Preparation of the Soil

Grow row or green manure crops on the site for at least 1 year before planting strawberries. This reduces weed and root-feeding insect problems.

Destroy grass sods before planting by spraying with dalapon at 10 to 20 pounds per acre. Apply it sometime between Sept. 1 and Nov. 15 when grass is 4 to 8 inches tall. If grass is low in vigor, apply fertilizer to furnish about 35 pounds of actual nitrogen per acre 2 weeks before spraying with dalapon.

Here is a good program to build up soils for strawberries:

1. First Year

- Disk the field often to kill weeds and grass, or
- Use dalapon to destroy grass sods (see above). If land has been fallowed or in sod for several years and soil fertility is high, plant strawberries early the following spring. If not, follow the program below:

2. Second year

- Disk early several times.
- Sow either buckwheat at 5 or 6 pecks per acre or sudan grass at 25 pounds per acre. Sow early—as soon as danger from frost has passed. Apply 400 pounds of 12-12-12 fertilizer per acre with the seeding.
- Disk or plow down the green manure crop just before full bloom. If the soil is low in phosphorus, work in about 1,000 pounds per acre of superphosphate.
- Sow 2 bushels of rye per acre in August; fertilize with about 400 pounds per acre of 4-16-16 or 5-20-20.

3. Third year

- Apply 100 pounds of actual nitrogen per acre on the rye in late winter or early spring.

- Plow rye as soon as you can work the land in the spring. Disk the soil several times to form a firm, fine plant bed.
- On sandy soils very low in fertility and organic matter, repeat the second-year program as outlined above. Otherwise set the strawberry plants about 2 weeks after plowing the rye.

Some growers prefer oats to rye for the winter cover before setting out strawberries. Oats will winter-kill and decay faster than rye, but oats will provide much less organic matter.

Rotations and Organic Matter

It is well known that any one type of crop grown year after year on the same site declines in vigor after a few years. This may be due to loss of soil fertility and organic matter, or an increase of soil-borne pests or toxins. Growers have known for many years that strawberries grow best on "new" land and on sites where strawberries have not been grown in recent years. Put strawberries in a rotation with other row crops that also includes green manure crops.

When to Plant

Plant strawberries early in the spring—as soon as the soil can be tilled. Plantations that are set early usually yield much more fruit. Fall planting is not a good practice for commercial production in most of Michigan, but it does succeed in northern Michigan where planting may be delayed in the spring and the ground has had a protective cover of snow during most of the winter. Some growers in northern Michigan regularly plant strawberries about Nov. 1. These fall-set plants get a fast start the next spring and make some growth before conditions are right for planting then.

Planting Stock

Some growers raise their own plants but renew their stock from time to time with plants from nurseries. Others with large acreages find it cheaper to buy their plants each year.

The value of good, sound planting stock cannot be stressed too highly. "Know your nurseryman and his stock of plants" is the best advice to follow in getting your strawberry plants.

If you grow your own plants, use one or more rows just for this purpose. Inspect them often during the year and remove all weak and

abnormal plants. This removes many diseased plants (especially those with viruses) which might infect the new fruiting field.

When digging for planting, choose plants with large crowns and large, light colored root systems. Avoid old mother plants and those with weak crowns or weak, dark roots. About 6 to 25 good strawberry plants can be produced for each foot of row, depending upon the season and variety. The **Robinson** variety often produces 25 plants or more per foot, while **Premier** and **Catskill** yield only half or two-thirds as many.

Dormant strawberry plants usually grow and yield better than those dug after growth starts in the spring. Most nurseries try to ship early while plants are still dormant. Some hold their plants in cold storage between 28 and 32 degrees F. to insure dormancy.

Unpack and inspect your plants when they arrive from the nursery. Put them in cold storage or heel-in until ready to plant. To heel-in choose a moist, well-drained spot away from the sun and wind, such as the north or east side of a building. Then put the plants in a shallow trench with the crowns flush to the soil surface. Fill the trench with sandy soil and pack it firmly about the roots. If the roots are dry, soak them in water for several hours prior to heeling-in. Then moisten the soil around the plants. You can keep them this way for about 10 days during cool weather. It is best, however, to transplant them as soon as possible.

If you hold plants in cold storage, pack them in plastic bags or in crates with damp peat moss or sawdust packed about their roots. Plants stored this way at 28 to 32 degrees F. grow better than those that have been heeled-in out-of-doors.

TABLE 4—Number of strawberry plants at various spacings needed to plant an acre

Spacing (feet)	Plants to an acre (number)	Spacing (feet)	Plants to an acre (number)
3 x 1.....	14,520	3½ x 2½	4,980
3 x 1½.....	9,680	3½ x 3	4,148
3 x 2.....	7,260	4 x 1	10,890
3½ x 1.....	12,446	4 x 1½	7,260
3½ x 1½.....	8,296	4 x 2	5,445
3½ x 2.....	6,233	4 x 2½	4,356

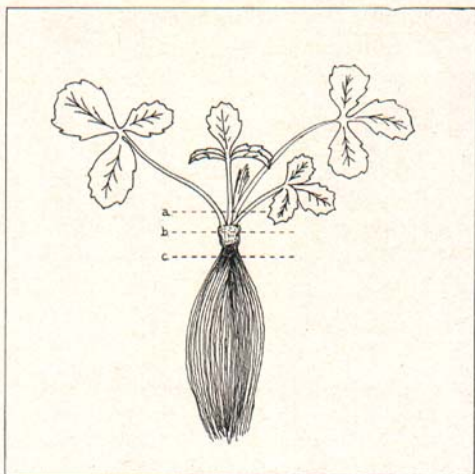


Fig. 9. Strawberry plant planting depths. Broken line "b" illustrates proper depth; line "a" - set too deeply; and line "c" - not deeply enough.

Number of Plants Needed for Planting

Set your strawberry plants about 24 inches apart in rows, with a spacing of 3 to 4 feet between rows.

The number of plants for various spacings on an acre of land is listed in Table 4. Order a few extra plants each time to use for re-planting in case some of the plants die in the original planting.

Setting the Plants

Transplanting machines do the planting job quicker and cheaper on large acreages than can be done by hand.

Plant your strawberries during cloudy weather in cool, moist soil. Plants from most nurseries arrive cleaned and trimmed, ready to be transplanted. If you dig your own plants, remove the old stolons, and all but 2 or 3 small crown leaves. While planting, keep the roots covered with wet peat moss or burlap, in shallow boxes or trays to protect them from the sun and wind.

It is very important to set plants at the right depth (Fig. 9) and to pack the soil firmly about the roots. Unless the soil is too wet, there is little danger of packing it too tightly. Keep crowns of the plants flush with the soil surface. If set too deeply, the crowns may become

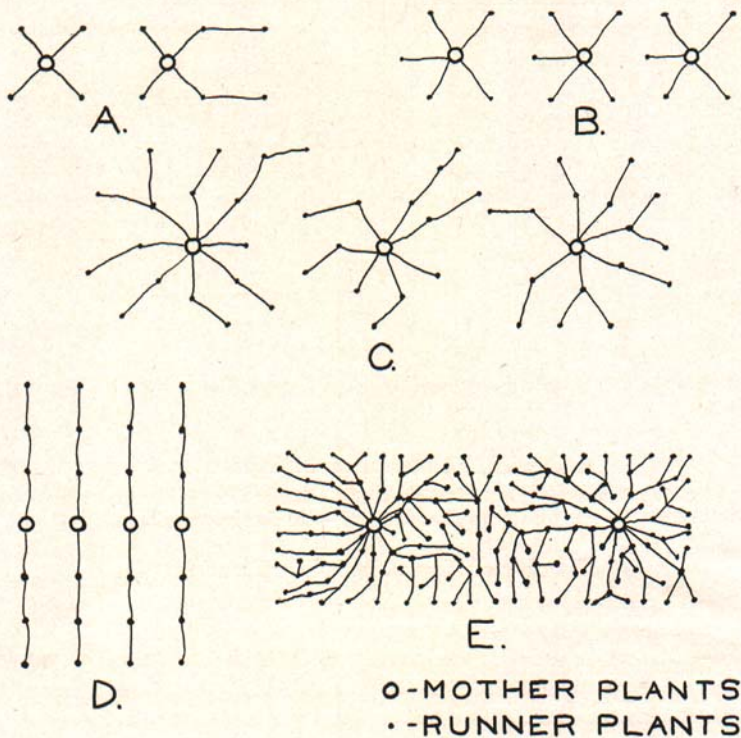


Fig. 10. Various systems of training strawberry plants.

covered with soil and soon rot. If set too high, the roots and crowns may become exposed and dry out after the soil has settled. If the soil is dry and hot, irrigate right after planting.

Starter Solutions⁴

When planting strawberries use starter solutions only on clay or loam soils. When planting on sandy soils, use plain water instead of starter solution.

Use mixtures high in phosphorus (10-50-10, 10-52-17, or 15-52-9) as starter solution fertilizers for strawberries at a rate of 3 pounds in

⁴For a more complete discussion on this subject see Michigan State University Extension Folder F-194, *Starter Solutions*.



Fig. 11. An excellent stand of strawberry plants trained to the matted row system of culture.

50 gallons of water. Put one cup of solution around each plant at time of planting.

Avoid using single-salt fertilizers for starter solutions on strawberries. They may cause severe damage to plants even when used at low levels. This is especially true for the nitrogenous fertilizers, such as urea, ammonium sulfate, and ammonium nitrate.

Systems of Training

Three main systems are used to train strawberries: (1) The matted row; (2) the spaced plant; and (3) the hill (Fig. 10).

Matted row—Set the plants about 24 inches apart in rows spaced 3 to 4 feet apart. Let most of the runners root during the summer to form a mat of plants 10 to 12 inches wide (Fig. 11). Remove runners formed after mid-August.

Advantages of narrow over wide matted rows are: (1) Easier to harvest all the fruit; (2) easier to keep weeds out of the rows; (3) larger berries are produced; (4) more light and air for the fruit, thus less rot and better keeping quality.

Spaced plant—Set runners by hand until the desired number have rooted. Remove later runners as they appear.

Hill—Remove all runners as they appear, allowing only the mother plants to grow (Fig. 7). Set the plants 12 to 18 inches apart in the rows with 12 to 18 inches between each pair of multiple rows. Use 2, 3, or

TABLE 5—Effects of five training methods on size of berries and decay of fruit per plant on strawberries (adapted from U. S. Department of Agriculture Farmers' Bulletin 1028)

Growing system	Yield per acre			Relative size (%)	Decay after 1 day (%)	Plants Sq. Ft. of row (No.)
	Total (qts.)	U. S. No. 1 (%)	Culls (%)			
9-inch spacing, 24-inch row.....	4,993	84	16	88	8	1.8
6-inch spacing, 24-inch row.....	4,760	80	20	80	10	4.0
Double-hill row.....	3,506	90	10	100	5	.7
30-inch matted row.....	2,331	57	43	62	26	30.0
12-inch matted row.....	2,098	68	32	72	16

4 rows per multiple and keep a space of about 2 feet between each set of multiple rows.

Comparison of training systems: Strawberries grown in a hill or spaced plant system will outyield those in a matted row. Berry size also is greater, and usually less rot occurs (Table 5). These systems need much more labor than the matted row.

Despite its faults, the matted row system is adapted to extensive type farming with machinery. It is the system used by most Michigan growers.

The hill and spaced plant systems are used mainly by market and home gardeners. They are well-suited for everbearing varieties.

MANAGEMENT DURING THE FIRST SEASON

Removal of Blossoms

Blossom clusters appear on strawberry plants shortly after planting in the spring and may continue to emerge for several weeks. Flower and fruit production lower the vigor of new plants and reduce the number of early season runner plants. Runner plants rooted early in the season yield more fruit the following year than do those rooted later. It is important, therefore, to remove most blossoms soon after planting. You may have to make only one or two trips through varieties like **Robinson** which produce only one cluster per plant. With varieties like **Premier** which produce several blossom clusters per plant you may have to make several trips to remove blossoms.



Fig. 12. Thorough tillage early during the year of planting is desirable to retard weeds and make a better condition for rooting of runner plants.

Spacing and Thinning Runner Plants

Under most Michigan conditions it is impractical to try detailed spacing of runner plants in large plantings. Some thinning can be done in matted rows during late summer hand-hoeing operations. Most growers trim off the plants formed late in the season with a rolling disk on the cultivator. Keep runners spaced about 6 inches apart to make 5 or 6 plants to a square foot in matted rows in late August.

Michigan growers use various methods of mechanical thinning. Some pull old-style dump hay rakes across the field at right angles to the rows. The tines rip up many late-set plants, leaving the earlier more deeply rooted runners. Side-delivery hay rakes also are used in a similar way.

Tillage and Weed Control

Till as often as needed to retard weeds; this will help the runners to root more readily (Fig. 12). To get good spacing of early runner plants avoid working the soil toward the plants when tilling early in the season. Till each row in the same direction every time to reduce uprooting of runner plants.

Hoe often enough to kill weeds between the plants. Till no deeper than 2 inches, since new roots grow near the tops of crowns and are cut off easily.

Continue tillage up to the first hard frost in the fall. Several weeds—chickweed, quackgrass, and sheep sorrel—continue to grow even in late fall and start growth early in the spring. It is very important



Fig. 13. A type of power hoe used in some Michigan strawberry fields.

to remove these late weeds before mulching. Mulch will protect weeds as well as strawberry plants.

You can use certain chemicals with tillage to help control weeds. Chemical weed control is discussed later under the heading, "Weed Control."

In Michigan many growers with large acreages now use power hoe equipment (Fig. 13).

STRAWBERRIES AS COMPANION AND INTERCROPS

In home and market gardens, strawberries can be grown as companion crops in the season of planting. Most early season vegetable crops—radishes, beets, carrots, lettuce—are good companion crops with strawberries. Plant vegetables between the berry rows at the usual distance.

Strawberries are suited also as intercrops in new orchards (Fig. 14), providing income from land which otherwise would yield no returns until the trees begin to fruit.

From 4 to 6 rows of strawberries can be grown between rows of young fruit trees for 2 or 3 harvest seasons. Remember to apply extra fertilizer to meet the needs of both crops.

FERTILIZER AND LIME

Since Michigan soils vary greatly in fertility, test your soil to find the best fertilizer needs for your strawberries.



Fig. 14. Catskill strawberries planted between rows of young sweet cherries in Leelanau County. Photo taken during the first harvest season.

If manure is used, apply 10 to 20 tons to an acre. Manure often contains weed seeds, causing problems which may offset part of its benefits. To avoid this, use well-rotted manure or apply fresh manure to the crop grown ahead of strawberries in the rotation.

If soil fertility and organic matter are both low, use a green manuring program for 1 or 2 years before planting strawberries (see section on "Establishing the Planting.") Otherwise, apply a 1:4:4 or 1:4:2 ratio, depending upon soil test and management group. Work it into the soil about 10 days before planting in the spring. On fall-planted fields, apply it very early in the following spring, before growth starts.

Apply 1:1:1 fertilizer as indicated by soil test about 4 weeks after setting the plants if growth is weak. Use enough to supply 30 to 35 pounds of nitrogen per acre. Repeat in 3 or 4 weeks if vigor still is low.

Strawberries need plenty of nitrogen early the first year to produce runners and build up good crowns. Strong plants in late summer and early fall are needed to form fruit buds for next year's crop. Where nitrogen is low, plants will be weak and have small light green leaves often tinged or spotted with red.

Unless plants are quite weak, avoid using nitrogen fertilizer in the spring of the fruiting year. Too much nitrogen at this time causes uneven ripening and soft fruit which rots easily. Remember that fruit yields depend mainly upon the condition of the plants during the preceding season.

If a low level of nitrogen is obvious in the spring, use fertilizer to furnish about 10 pounds of nitrogen per acre. You can put this through the irrigation system for quick responses. If urea solutions are put on with a spray rig, use 5 pounds per 100 gallons of water and use 200 gallons to an acre. Apply again 10 days later if vigor is still low.

Lime seldom is needed since strawberries grow well on soils ranging from pH 5.0 to 7.5.

IRRIGATION⁵

In most years there are times when irrigation could help many Michigan strawberry plantings. During drought, it hastens growth of runners in the first season and increases size of berries in the fruiting season. A sprinkler irrigation system also is a safeguard for protecting blossoms from frost damage.

Keep these things in mind when irrigating strawberries. In using them, remember that soils may vary from field to field:

- Begin to irrigate before plants show the effects of drought. A Bouyoucos meter and moisture blocks or similar devices are useful to determine when to start.

- Strawberries need about 1 acre-inch of water in each week of the growing season. Irrigate if rainfall fails to supply this much.

- During any one setting, apply these amounts of water:

Sandy soil: ½ to 1 inch

Loam soil: 1 to 1½ inches

Clay soil: 1½ to 2 inches

- Most sandy soils can absorb an inch of water without much runoff when it is applied over a period of 75 to 80 minutes. Heavier soils need 2 hours or longer to absorb this amount.

MULCHING

Winter mulches protect strawberry plants from physical freezing damage. In mid-winter most plants can withstand 15 degrees F. without injury, if "hardened" by exposure to gradually cooling temperatures. Below 15 degrees F. will damage exposed plants at any time. Damage may also occur at temperatures above 15 degrees F. if plants have not been hardened.

⁵For a more complete discussion see Michigan State University publications: E-309 *Supplemental Irrigation in Michigan* and E-320 *Irrigating Small Acreages*.



Fig. 15. A good mulch, properly placed, insures clean bright berries with but little rot.

Mulches protect plants from heaving damage on heavy soils. Heaving usually is not a problem on sandy soil.

Mulches result in cleaner berries and more pleasant harvest conditions in the spring (Fig. 15).

Apply mulch in late fall or early winter after a week of near-freezing temperatures. Put on a 2-inch layer of grain straw or marsh hay. This takes about 2 tons to an acre.

If mulching is delayed until spring on sandy soils, apply about 1 ton per acre just after the first blossoms have set fruit.

Shake out the mulch and spread it evenly on the field. Mulching machines apply a uniformly thick layer around the plants.

WEED CONTROL

Control of weeds in Michigan strawberry plantings each year costs thousands of dollars. Methods of weed control with a minimum of hand work are needed in these days of high labor costs. You can save much labor by using certain chemicals (called "herbicides"), special types of tillage equipment, and geese.

Herbicides

You can buy power spray equipment just for applying herbicides or adapt your pest control equipment for weed spraying. Use low-

pressure nozzles which make a flat, fan-shaped spray pattern for spraying herbicides. Use low nozzle pressures of about 50 pounds.

It is very important to apply herbicides to strawberries exactly as directed. Calibrate the sprayer ahead of time to be sure the right amount of herbicide is put on each acre:

(1) Measure the width of the boom in feet. Divide this figure into the number 43,560 (number of square feet in 1 acre). If the nozzles are arranged so that only the rows are sprayed, divide half of the width of the boom into 43,560. The answer is the number of linear feet that the boom must travel to cover 1 acre. Measure and stake this distance in an open field. Fill the supply tank up to the "full" mark with water. Spray the distance measured between stakes; note the speed of the tractor while traveling this distance.

(2) If the tank has no volume gauge, refill it with water, making note of the gallonage needed to bring it to the "full" mark. This is the number of gallons sprayed per acre. About 50 gallons of water per acre is a good volume for applying most herbicides.

(3) Add the proper amount of the herbicide to the volume of water needed to spray an acre, as measured above.

2, 4-DES (formerly called **Sesone** and **Crag Herbicide No. 1**)—is very good for killing germinating weed seeds and seedlings. It does not harm established weeds or strawberry plants, and it is not harmful to quackgrass and other weeds which grow from underground stems.

Use 2, 4-DES at a rate of 3 or 4 pounds per acre. Apply it right after the ground has been cultivated. Since it becomes active only in moist soil, apply it shortly after irrigating during a period of drought. If heavy rain occurs after applying 2, 4-DES, most of it will be washed away and a new application must be made.

Use 2, 4-DES about 2 weeks after planting strawberries. It cannot be used during the period of early runner formation, since it retards their rooting.

Make a second application of 2, 4-DES in August after the early runners have rooted. Further applications can be made at intervals of 4 weeks.

You can use the amine salt of 2, 4-D (2, 4-dichlorophenoxyacetic acid) for weed control in newly renovated fields. Never use 2, 4-D on strawberries in late summer or fall, since it interferes with fruit bud formation which occurs at that time. Never use it in equipment that is used also for spraying insecticides and fungicides.

Geese

When properly managed geese grazing in a strawberry planting keep grasses under control. They prefer juicy grasses, but also may forage on tender seedlings of certain broadleaved weeds.

About 6 to 8 geese per acre are usually good on strawberry plantings. You must put a poultry fence around it to confine the geese. Make shade available together with a feeding and watering shelter. Shift the shelter occasionally from one spot to another around the field. This prevents damage to the plants from goose traffic in one spot. You must provide water and feed, but keep the feed low so the geese will forage on grasses in the strawberry planting. Give them a balanced diet and provide vitamins to keep them active and in good health.

You can use geese in new plantings and during spring of the fruiting year. Remove them about 3 weeks before harvest of the berries begins. Geese are also useful to graze grass in renovated fields.

Specialized Tillage Equipment

Many types of tillage equipment are now available for cultivating strawberries. Self-propelled power hoes, rotary-type tillers, or tractor drawn sulky hoes save hand labor in plantings. Some of this equipment is quite expensive, but on large operations it soon pays for itself in labor-savings. The equipment often is designed for row crops in general, so it can be used also on other crops.

SPRING FROST PROTECTION

In southwestern Michigan, strawberries begin to bloom about the first of May and continue to bloom heavily through May 20 to 25. During most springs, frost will kill some unprotected strawberry blossoms. Most locations in Michigan have at least one killing frost—sometimes as many as 10 or more—during the bloom period. Since blossoming is spread over a period of 3 or more weeks, it is unlikely that all blossoms in a planting would be frozen. In June-bearing varieties, such as **Robinson** and **Premier**, those that are killed, though, are not replaced. Unlike apples, peaches, and other fruits, berries growing from sound blossoms will not be much bigger because of the destruction of other

blossoms. Thus, blossoms killed by freezing means a real financial loss due to lower yields of fruit. Also, freezing damage occurs most often to early blossoms than to later ones. This loss is especially serious since the largest and earliest berries come from the early blossoms, and these early berries bring higher prices than later fruit.

Mulches, while sometimes effective for protecting strawberry blossoms from frost, delay ripening of the crop. Growers who use mulch for frost control often miss the early market when prices are highest.

Fires or infra-red heating units are too expensive. Smudge pots are effective in Michigan **only** on those very rare nights when air conditions are just right to produce a "layering" effect.

Portable sprinkler irrigation has given Michigan growers an effective and economical means of protecting their strawberry blossoms. It is used on over half of the state's strawberry acreage.

In using sprinklers for frost protection, space lateral lines from 70 to 90 feet apart, and the sprinklers about 60 feet apart in the lines. Use special frost nozzles and keep pressures at the sprinklers at 70 pounds or higher to get proper coverage. "Fogging" should occur at these pressures. This "fog" tends to drift and disperse well beyond the normal range of the sprinklers.

Start to irrigate for frost protection when the temperature at ground level is 34 degrees F. Some growers use their own "tricks" to find the right time to start irrigating. Some look and feel for ice crystals on leaves in the lowest parts of their plantings. Some watch for frost on sheet metal objects placed at the edge of fields. Others place shallow pans (such as pie plates) of water in the rows and watch this for formation of ice.

Continue to sprinkle as long as there is ice on the plants.

Where water supplies are short, sprinkling 20 to 30 minutes out of every hour may give some protection. This works only when temperatures are at, or just below, the critical freezing point. At lower temperatures, such intermittent irrigation usually fails to prevent serious frost injury.

The source of water for sprinkling has no effect on frost protection. You can use water from both deep and shallow wells, lakes, ponds, and streams.

HARVESTING AND MARKETING

General

The first ripe berries appear in Michigan strawberry fields about 30 days after the first blossoms are fully opened. Pick soft-fleshed varieties like **Robinson** for distant shipping when about 25 percent of each berry is greenish-white. Pick most varieties for local markets and processing with full red color.

Pick most varieties for fresh market every other day. In very hot weather with high humidity, pick **Robinson** and other soft varieties every day. If not picked often enough and if all the ripe fruit is not picked each time, soft berries will be mixed with firmer fruit during later harvests. Berries for fresh market keep and look better longer if picked during the early part of the day when it is fairly cool. For processing, pick every 3 or 4 days.

Varieties differ in length of season during which they produce ripe berries. **Premier** and **Sparkle** often have long picking seasons of 3 or 4 weeks. On the other hand, **Robinson** and **Catskill** may have a picking season of less than 2 weeks in some years.

Method of Picking⁶

Fresh Fruit Market—"Pick" rather than "pull" berries from the plants when the fruit is to be sold on the fresh market. Pinch the berry

⁶Michigan State University Extension Folder F-92, "How to Pick Strawberries", contains detailed and illustrated information on picking strawberries. It is a handy booklet for teaching picking crews.

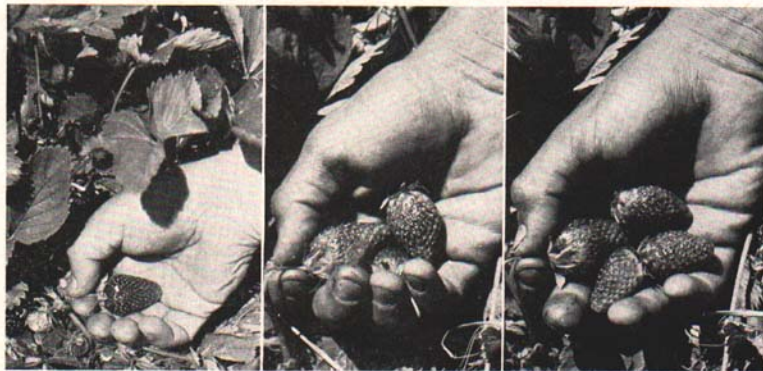


Fig. 16. Pick strawberries for fresh market by pinching and twisting the stems rather than pulling the fruit.

stem from the plant with the thumb and forefinger, leaving about one-half inch of stem still attached to the berry (Fig. 16). Place the berries gently in the boxes to prevent bruising.

Hold only 2 or 3 berries in the hand at one time to prevent squeezing them. Avoid "snapping" the berries from the plants, thus leaving stems and caps in the field. Such berries do not ship well and break down faster than those with stems.

Commercial Processing Market—Processors prefer strawberries with caps removed. The **Catskill**, **Tennessee Beauty**, and **Sparkle** varieties are easy to pick, leaving the caps in the field. **Premier** is fairly hard to cap, and **Robinson** caps are very hard to remove.

Pickers

When picking for the fresh market, you will need 5 or 6 pickers per acre each day where yields are fair. Where yields are high, you will need more pickers. When picking and capping for processing, you will need twice as many pickers as for fresh market picking.

Thick weeds and heavy strawberry foliage slow down the pickers. You will need more pickers per acre in such plantings than on clean fields with average foliage. You also may have to pay pickers more for each quart of fruit harvested in such fields.

Supervise the pickers closely. Assign field foremen to each picking crew to see that the berries are picked properly. It is the duty of the foremen to teach their workers how to pick properly.

Most pickers in Michigan are paid by piecework; that is, either by the quart or by the pound. They can be paid as they deliver the fruit to the packing shed, or receive tickets which are turned in for cash at the end of the day or week. Some growers retain a bonus for each quart or pound of berries picked, which is paid at the end of the season. This is done to encourage pickers to stay through a season.

Picking Containers

Strawberries usually are picked into quart veneer boxes which the pickers carry in light trays or carriers. Carriers with a capacity of 6 to 10 boxes are used most often. Ventilated picking lugs (V-lugs) are used by some growers in northern Michigan who sell to processors (see Fig. 17).



Fig. 17. A view of a "V-lug" showing its detachable handle. This type of lug is used by some growers in northern Michigan who ship to processors.

Care after Picking

The keeping quality of strawberries after harvest depends upon several factors: (1) The variety; (2) stage of maturity when picked; (3) temperature of the berries when picked; (4) care in handling; (5) temperatures at which berries are held after picking; and (6) presence of rot-causing organisms.

The shelf life of strawberries usually is shortened by about one-half for each rise in temperature of about 15 degrees F., where other factors are equal. Berries picked in early morning, when they are fairly cool, and kept in the shade will keep better than those picked during mid-day, or those left in the sun after picking.

Most growers have portable packing sheds at the edges of their fields. They move these from one section to another as the harvest progresses. Pickers bring the berries from the fields to the sheds. The berries then are inspected and put into crates by the packing crew.

The market life of fresh strawberries can be extended by placing them in cold storage. If they are to be held for a day or longer, keep them at 32 to 35 degrees F. If held for a period of only a few hours, keep them at about 45 degrees F. Remember that berries tend to

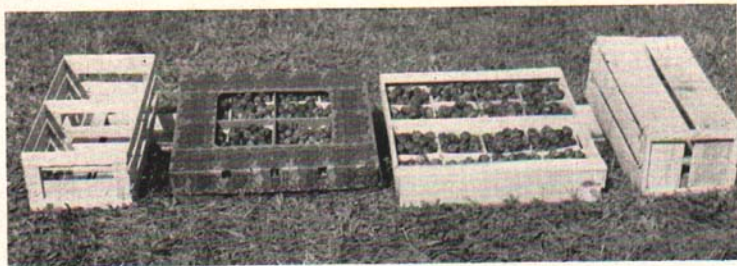


Fig. 18. Type of shipping crates sometimes used for marketing Michigan strawberries.

"sweat" due to condensed moisture when held below 45 degrees F. This moisture detracts from their appearance and hastens rotting of berries held for short periods in cold storage.

Market Containers

Michigan strawberries usually are sent to market in 16-quart wooden crates. Wire-bound crates are now becoming more popular, but the nailed crate still is used widely. Wooden and cardboard flats holding 12 and 16 quarts have very limited use (Fig. 18).

The quart veneer box is the standard market container in Michigan. Pint boxes have not gained acceptance in the state.

Berries for processing usually are shipped in lugs furnished by the processors.

RENOVATION OF THE PLANTATION

General

Michigan strawberry plantings commonly are harvested for 2 and sometimes 3 seasons and then plowed down. In well kept plantings the crop of the second season may exceed that of the first. With intensive culture, as in the hill or spaced plant systems, plantings can be kept for several years.

Some fields under matted row culture have produced well for 5 years or longer. This is unusual and occurs only under good cultural practices.

The number of years that a planting can produce well depends upon such factors as weeds, diseases, insects, and general vigor of the plants.

TABLE 6—Effect of mowing leaves after harvest on yield of strawberries the next year*

Date mowed	Incr. (+) or Decrease (-) in Yield Comp. to Unmowed		
	Blakemore (%)	Joe (%)	Premier (%)
July 1.....	+22.0	+13.5	+12.1
August 1.....	+11.8	- 7.7	- 0.1
September 1.....	-10.5	-10.6	-24.2

*Data from U. S. Department of Agriculture Farmers' Bulletin 1028.

Where weeds like quackgrass, sorrel, or chickweed have been hard to control, it is often wise to plow the planting after the first crop year.

When keeping a field over for another year, be sure to renovate the planting properly. First, mow the old foliage as close to the ground as possible, but high enough to avoid injuring the crowns of the strawberry plants. Mow right after the last picking. Early mowing results in larger yields the year after renovation than does late mowing (see Table 6).

Trim the edges of the old rows, leaving the old centers undisturbed to a width of 8 to 10 inches. The crown of a single strawberry plant is like the trunk of a tree. It grows new tissue and side branches each



Fig. 19. Renovating a two-year-old field right after harvest with a rotary-type tiller; plant row width can be adjusted according to number of "beaters" or "fingers" removed from center of tiller drum.

year. If you keep it vigorous, a single strawberry plant can produce crops for many years.

One good method for narrowing the rows is with a rotary-type cultivator (Fig. 19). Remove teeth at the desired location and distance. This leaves a narrow strip of plants in the center of the row.

PROPAGATION OF PLANTS

Strawberry varieties are reproduced by stolons (runners). They cannot be reproduced from seed. Seeds from a single berry grow plants which may vary widely from each other. Some of the berries may be light, some dark; some plants may produce early fruit, others late.

Use of crown divisions is impractical except for certain ever-bearing varieties which develop only a few runners.

Grow strawberry plants for propagation, on deep, light-textured soils. Such soils let the roots develop fully; they also dry out fast in the spring and can be dug sooner than plants on clay or loam soils. The roots break less during the digging operation on light-textured soils.

In growing plants, you must set good healthy stock early in the spring. If you use virus-free stock, most varieties will yield at least 100,000 plants to an acre the following spring. This number may vary widely due to the variety, the season, presence of pests, and cultural care. Varieties like **Robinson** and **Dunlap** may yield 300,000 or more plants per acre under good conditions.

II. STRAWBERRY INSECTS AND NEMATODES

By RAY HUTSON¹

Numerous insects may infest a strawberry bed. Aside from white grubs, leaf rollers, spittlebugs, and weevils, few other insects warrant spraying or other special control measures. Nematodes—tiny thread-like worms—are included.

When leaf rollers are abundant, regular spraying may be needed. However, in all plantations preventive measures are an effective supplement to spraying for control of strawberry pests. These include mowing after harvest, clean tillage, and the removal of weeds and rubbish from the borders of the plantation, together with the use of healthy planting stock, short rotations, and proper management methods. In strawberry plantings, nematodes cause many puzzling conditions and need more attention, especially when establishing a planting.

White Grubs

These are among the most troublesome and destructive insects attacking the strawberry. They feed on the large roots and in the crowns, causing the plants to wilt and die. The grubs (larvae) of the common May-beetles or June-bugs live and feed in the ground for 3 or more years. They are most abundant in land that has been in grass sod for several years. Before planting strawberries, plant such land for at least a year to a cultivated crop not affected by white grubs.

You can protect strawberry plants from white grubs by using a soil insecticide before the plants are set (see Strawberry Root Weevil).

Strawberry Leaf Roller

This is a small greenish or grayish caterpillar with a brown head. When fully grown, it is about a half inch long. There are 3 to 4 generations per season. The larvae hatch from eggs deposited by small brownish moths often seen after mid-April among infested strawberry plants.

¹Professor and Head of the Department of Entomology.

Damage by strawberry leafroller is caused by the feeding of the caterpillars inside the leaflets which are tied together with silken threads. Leaflets injured by the strawberry leafroller show a ragged appearance with many brown, dead, crumpled leaflets.

The best control for strawberry leaf rollers is 25 percent DDD (TDE) emulsion, 2 quarts per hundred applied just before bloom on bearing plants. The 50 percent wettable powder DDD at 2 pounds per hundred also does a good job. On young plants 2 to 3 sprays during the season are necessary. Many other materials have been used against leaf roller. Lead arsenate at 3 pounds per hundred gallons of spray before bloom does a good job, but has to be thoroughly done. Parathion 15 percent wettable powder at 1 pound per 100 gallons of spray has been used successfully as has 2 pounds 25 percent wettable powder malathion. With lead arsenate, parathion, and malathion extra care in coverage is important.

Strawberry Weevil or "Clipper"

Although this insect has never been widespread in Michigan, occasionally it is abundant in some localities. It is a small, black or reddish brown snout-beetle about one-eighth inch long; it appears just as the strawberry buds begin to open. The injury is caused mainly by adult females which puncture the unopened buds and then clip the stalk some distance below the injured bud. This causes the bud to wilt, dry up, and fall to the ground. Dust the plants with 3 to 5 percent DDT or $\frac{3}{4}$ percent rotenone just as the beetles begin to damage the buds. Control is also helped by clean cultivation and early inspection for this pest.

Strawberry Root Weevil

The strawberry root weevil adult is widely known as a nuisance in dwellings; it is the habit of this beetle to crawl into protected places. The footless, white, brown-headed grub (larva) varies in length at different stages; when mature it is about one-third inch long. It feeds on strawberry roots (Fig. 20). On well watered sites (irrigated or otherwise) these grubs can become numerous enough to eat the roots from the plants. For the work of this pest, examine the roots of all stunted strawberry plants especially if noticed in late fall or early spring.

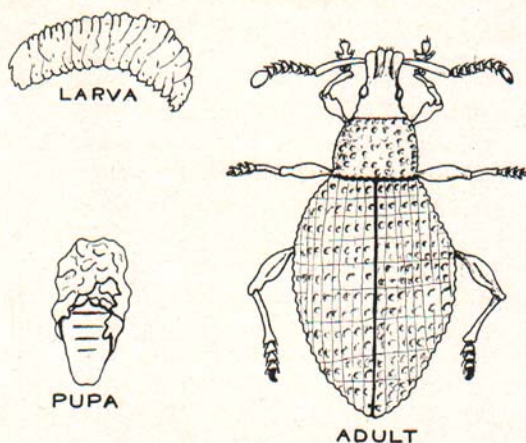


Fig. 20. Various stages of the strawberry root weevil. The footless, white to grey, brown-headed larvae feeds on strawberry roots during early spring and late fall. It varies in length at different stages; when mature, it is about 1/3 inch long.

Adult beetles appear about harvest time. They do not feed heavily but cluster beneath the foliage for a few days before laying eggs. The beetles travel on foot; they cannot fly.

Control the strawberry root weevil by treating the soil with 10 pounds (actual) of chlordane per acre before setting the plants. Apply it as a dust or spray to the soil surface and disc immediately 4 inches deep or if available apply with a fertilizer. Such a treatment will also reduce damage from other soil infesting insects such as white grubs. Aldrin, dieldrin, and heptachlor at 5 actual pounds to the acre are also effective against strawberry root weevil as a soil treatment. When applying these materials, follow the instructions for the use of chlordane. After harvest, adult beetles can be killed by spraying with either 2 pounds of chlordane (50 percent) to 100 gallons of spray, or with aldrin, heptachlor, dieldrin or parathion at dosages commonly used against chewing insects.

Spittlebug

Spittlebug infestation is recognized by the foam-like spittle masses on the plants. Before bloom, apply 2 pounds of 50 percent wettable DDD (TDE) powder plus 1/2 pounds of 50 percent wettable dieldrin

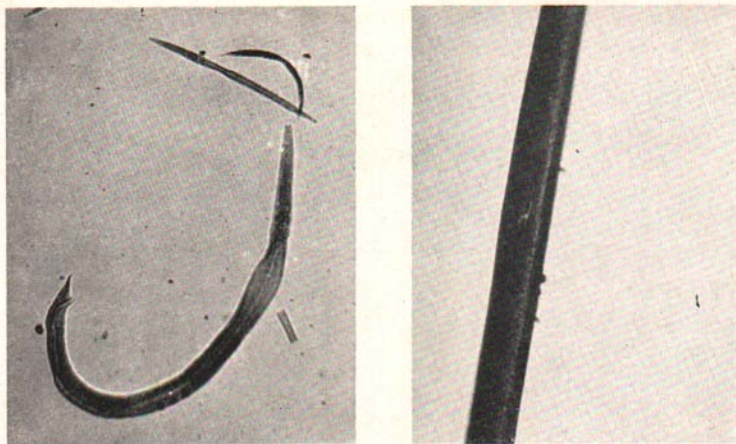


Fig. 21. To the left is a nematode of the type which infests plant roots. The strand in the photo to the right is a human hair.

powder to 100 gallons of water. If spittlebug foam masses appear on the plants after bloom, spray immediately with 2 pounds of 25 percent wettable diazinon powder to 100 gallons of water or 1 pound of 15 percent wettable powder parathion or dust with 1 percent parathion.

Methoxychlor at the rate of 1 quart 25 percent emulsion per 100 gallons has given excellent control of spittlebug when used at 200 gallons per acre. It can be applied within 14 days of harvest.

Root Aphids

To help control root aphids, dip strawberry plants in nicotine sulfate or chlordane before setting. Use one pint of nicotine sulfate to 50 gallons of water containing 2 ounces of a spreader such as one of the commonly used household detergents. One pound of 50 percent wettable powder chlordane in 50 gallons of water has given equally good control. It is necessary to keep the chlordane mixture well stirred.

Nematodes

Nematodes are round-bodied worms (Fig. 21) belonging to the same group as the "hairsnakes". They commonly infest the digestive systems of animals. There are thousands of varieties of nematodes inhabiting soil, on plants, in decaying vegetation, in fact almost anywhere one

looks for them. Some are harmless. Some of them are beneficial because they feed on other nematodes and other pests. Certain root knot and root lesion nematodes cause strawberries to become unthrifty and unproductive.

Identification of the kind of nematodes present is a necessary step in any decision to apply control measures. This is not easy because infested plants often show symptoms very like those resulting from lack of adequate nutrients, unadapted strains, poor care, disease, etc. Because there are so many kinds of nematodes found in strawberry fields, and because of their small size, only a microscopic examination can be relied upon for identification. The only exception to this is the presence of northern root knot nematode galls on strawberry roots.

As the northern root knot nematode (*Meloidogyne hapla*) feeds on roots, it injects a substance that causes swellings (knots or galls) on the smaller roots. This particular root knot nematode found on strawberry feeds on many other crops and weeds. Northern root knot nematode may be introduced into a field by any transplanted crop, machinery, drainage, etc. Infested strawberry plants show a variety of symptoms, such as poor production of fruit on new plants, or galls on the roots. Strawberry plants with galls on the roots are not legally salable.

Root lesion nematodes are not responsible for galls on the roots of strawberries. Damage by root lesion nematodes results from their habit of moving about in the soil and "pasturing" on the strawberry roots, with their sharp needle-like feeding apparatus. Injury and death of portions of the roots cause unthriftiness and unproductiveness. Root lesion nematode damage is more difficult to recognize than root knot nematode damage. About the only readily seen symptom of root lesion nematode work is a tendency toward abnormal root branching and clumping at those points where heavy nematode feeding has occurred.

The essential steps in nematode control on strawberries are:

- (1) Determine the presence and number of plant parasitic nematodes.

Root knots on strawberries indicate root knot nematodes. Root lesion nematodes require microscopic examination for recognition.

- (2) After diagnosis, decide on treatment.

The number of root knot nematodes in a field can be reduced to a low point by controlling weeds and using a long rotation of grasses and grains between strawberry plantings. Root knot nematodes can also be controlled by fumigation.

Fumigate the land heavily infested by root lesion nematodes.

Fumigation is a profitable operation if there is a heavy population of harmful nematodes on land to be planted in strawberries. However, fumigation at present is a custom operation requiring special machinery. Because of this fact and the rapid advances in fumigation knowledge and "know-how", consult your County Agricultural Agent for help with fumigation for nematode control.

Some of the better known materials for nematode control are: ethylene dibromide, (EDB), 1, 2, dibromo-3, chloropropane; dichloropropene; dichloropropane mixture; and dichloropropene. However, the keen interest on the part of pesticide manufacturers has created many other effective materials, but we have not had enough experience in their use. Costs, safety to the plants, availability of fumigants and fumigating equipment, the time of year, soil, and the kind or kinds of nematodes present must all be considered.

Tarnished Plant Bug

The adult tarnished plant bug is about 3/16 inch long. It varies in color through various shades of brown, and is extremely active. The front wing-tips cross each other. The young nymph is green and slightly resembles a light green aphid.

This is a sucking insect whose feeding damage is apparently magnified by saliva secretions injected into plant tissues. Many kinds of rapidly growing plants are attacked by this insect.

The adult spends the winter hidden wherever there is protection. Lush growing or weedy strawberry plantings are favorite overwintering places.

Tarnished plant bug damage on strawberries is most noticeable as hard, dry, non-growing, or dead areas in the fruit. Sometimes only a small portion of a berry is affected; sometimes the entire fruit. Small wounds usually result in misshapen berries; occasionally the entire berry ceases to grow and resembles a greenish brown button. These damaged berries commonly are called "buttons", "catfaces", or "monkeyfaces".

Control of tarnished plant bug is complicated by at least three things: (1) Many insecticides do not affect them; (2) they are active;

and (3) the available effective materials must be used carefully to avoid chemical residue on the fruit. Application of any material suggested must be timely and thorough.

The pre-bloom application suggested for spittlebugs will take care of overwintering tarnished plant bugs already in the planting, but migration from the winter quarters may reinfest the field after bloom. About the only material that can be used after bloom is 3 pints of 50 percent methoxychlor emulsion in 100 gallons of spray. Apply at 200 gallons per acre. Lindane controls the tarnished plant bug but is not suggested on account of possible effect on flavor. Consult your county agent on this point.

III. STRAWBERRY DISEASES

By R. H. FULTON^s

LEAF DISEASES

Two different fungi cause leaf spotting on strawberries in Michigan. Where severe, the lesions may occur on leaf stalks and fruit stems, sometimes girdling them and causing the death of the flowers and young fruit. This not only reduces yield, but lowers the grade of harvested berries and the vigor of plants. The leaf spot fungus (*Mycosphaerella fragariae*), causes spots with white centers and purplish borders (Fig. 22). The leaf blight fungus (*Dendrophoma obscurans*), causes egg-shaped to triangular areas that are light brown to red in color and are confined to tissue between leaf veins (Fig. 23).

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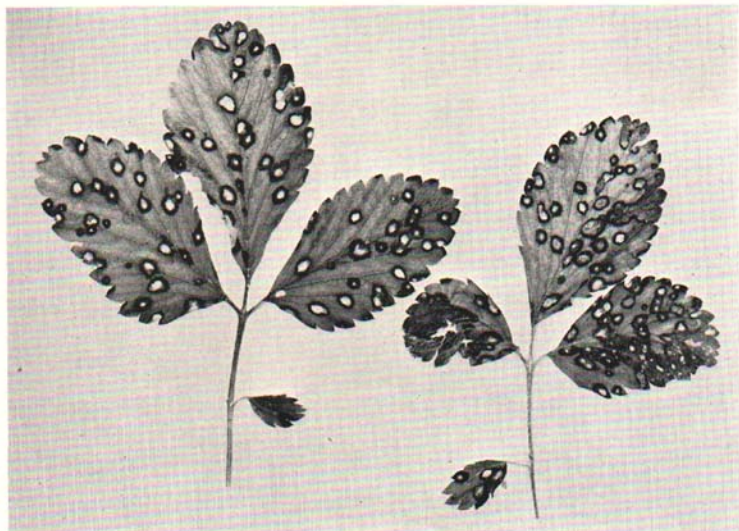


Fig. 22. Strawberry leaf spot on the upper side of leaves. Note the white centers and the dark borders of the spots.

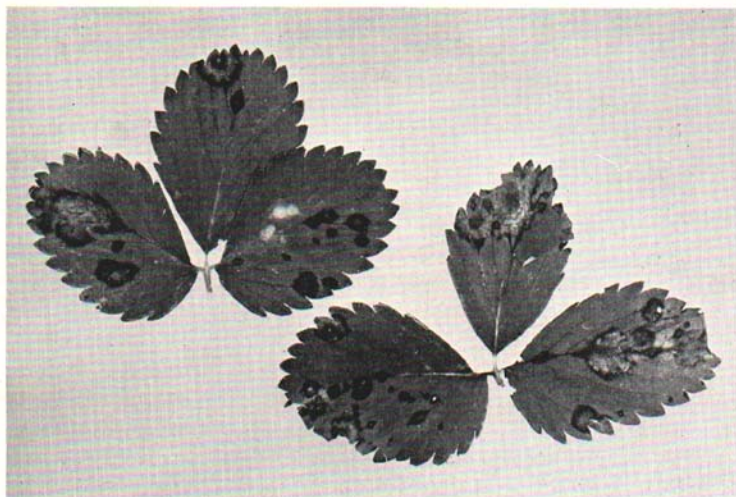


Fig. 23. Strawberry leaf blight on the upper surface of leaves. Note the characteristic V-shaped spots formed.

TABLE 7—Relative resistance of strawberry varieties grown in Michigan to some common diseases

Variety	Leaf diseases		Red Stele Root Rot
	Spot	Blight	
Blakemore.....	S	M	S
Catskill.....	R	S	S
Dunlap.....	S	S	S
Earlidawn.....	R	M	S
Empire.....	R	M	S
Fairland.....	S	S	R
Jerseybelle.....	M	M	S
Plentiful.....	R	S	R
Pocahontas.....	M	S	S
Premier.....	R	R	S
Redcrop.....	S	S	R
Redglow.....	S	S	R
Robinson.....	R	S	S
Sparkle.....	S	M	R
Surecrop.....	R	M	R
Tennessee Beauty.....	R	R	S
Vermilion.....	M	M	R

R—Resistant; M—Moderately susceptible; S—Susceptible.

The recommended sprays to control leaf spot and leaf blight for young and bearing plantations can be found in Extension Bulletin 154, Spraying Calendar. For information on varietal resistance, note Table 7.

ROOT DISEASES

Black Root

Black root rot is common in Michigan strawberry fields and causes weak, stunted plants. Its effects are most severe during drought, especially in the picking season. On hot days the plants wilt and then recover during the night; but, if dry weather persists, the plants die with the berries hanging green and shriveled.

Young, tender roots of affected runner plants have reddish-brown to black colored lesions. These rotting areas may affect part or all of the root, causing a darkened shriveled root. Do not confuse black root with red stele root rot. In black root the signs of the disease are in the outer part of the root, while the inner core (stele) remains a normal white.

Black root is caused by several soil-inhabiting fungi which invade the root tissues. Damage to roots by drought, fertilizer, insects, nematodes, winter injury, or any other injury to the roots allows the fungi to enter and cause the rot. To lessen black root rot, use healthy plants with clean roots for starting new plantations. Use mulches to protect the plants from winter injury. Apply soil insecticides for control of soil insects and nematicides for nematodes.

Red Stele Root Rot

In terms of known losses and difficulty of control, red stele root rot is the most serious strawberry disease in Michigan. It is caused by a fungus (*Phytophthora fragariae*), which grows best under cool, wet soil conditions in early spring and late fall. It spreads from root to root, plant to plant, and over entire fields in drainage and flood waters by means of swimming spores. The disease is, thus, most common in low and wet parts of fields.

The fungus forms thick-walled resting spores which stay dormant in the summer and live in the soil for many years. Soil has been known to carry living spores for 12 years, even when crops other than strawberries were grown. The fungus is not known to attack other crops.

Effects of the disease are seen best in the spring just before and into fruiting time. Plants are stunted and make but few runners. The older and outer leaves dry up, making the plant seem to shrink as the spring season progresses. The center or younger leaves are small with short stems, making the plant seem "to hug" the ground. Often the center leaves are deep metallic blue in color.

Red stele disease is easy to identify by examining the roots. In the first stage many small, fibrous, root branches are lost. The remain-



Fig. 24. Healthy and diseased strawberry plants. Left—healthy plant. Right—plant showing effects of the red stele disease. Note the absence of small feeding roots as compared with the normal root system.

ing main roots are bare and white like a group of "rat tails" (Fig. 24). Some or all of these main roots may show rot beginning at the tips. When split open lengthwise with a knife or thumbnail, some of them will have red cores extending for some distance into the otherwise white root (Fig. 25). When the core of the root is brownish or red in color, the trouble can be positively identified as red stele. This symptom is known for no other disease.

Because the fungus does not thrive in warm soil, surviving plants send out new clean roots as the weather and soil get warmer. They may appear to recover during the summer, but this condition is only temporary; as soon as cool, wet soil conditions return, the disease will attack these new roots. Crop losses,

thus, are more severe during the second fruiting season than the first.

The prevention of red stele is its best control measure. Select a planting site that has good soil drainage, preferably located where water from adjoining land will not drain through it. Start new plantings with certified, state-inspected stock only. Avoid using illegal, free neighborhood, uninspected plants. Use your own machinery for

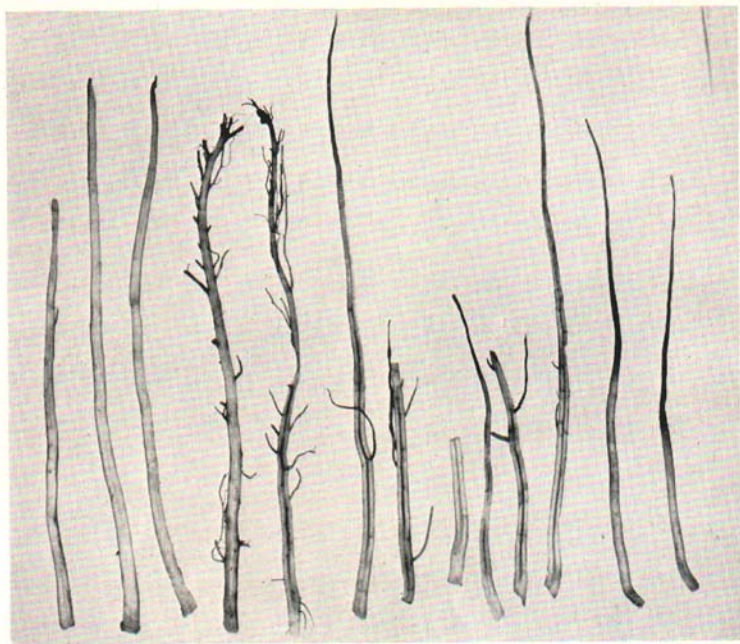


Fig. 25. Strawberry roots showing symptoms of the red stele disease. Left — diseased roots showing dead, discolored root tips. Diseased roots split lengthwise to show the reddened core; symptoms. Right — normal roots split lengthwise to show the absence of the red center.

setting out the field and for general cultural practices. If equipment is borrowed, clean off all soil and plant debris before use. If the planting site is known to be free of red stele and you wish to grow resistant varieties, then obtain Michigan state-certified stock **only**. At present, Michigan is the only state that requires nursery stock of resistant varieties to be grown on soil free of the red stele fungus.

To date, rotation, spraying, soil disinfection, and dipping plants in chemical solutions have been of no practical value in controlling red stele disease. If you have red stele in your soil, the **only** control method known, at present, is to use resistant varieties.

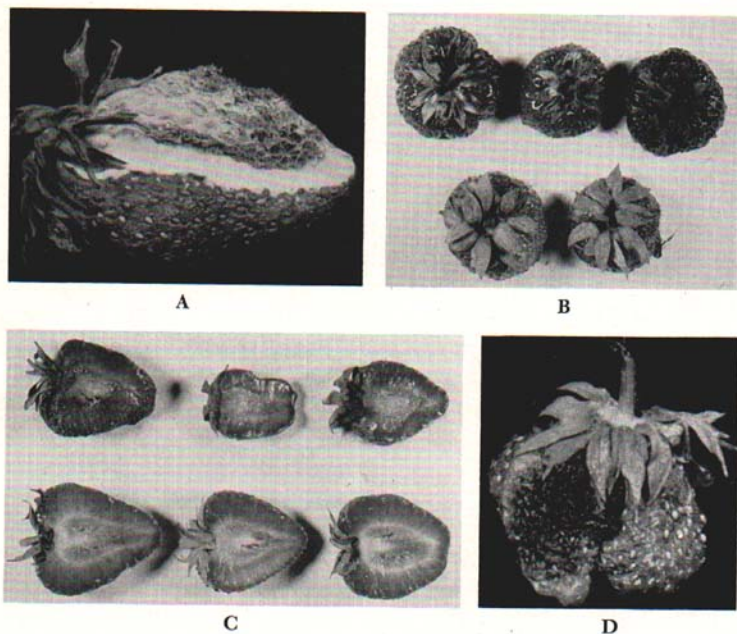


Fig. 26.

- A. Berry affected by gray mold fungus.
 B. Stem-end fruit rot. Note dead infected caps compared to healthy.
 C. Sectioned fruit showing internal symptom. Bottom healthy; top infected with stem-end fungal rot.
 D. *Rhizoctonia* brown rot. Note dark spongy area.

FRUIT ROTS

There are several fruit rots caused by fungi, but they all have one trait in common—they can infect a berry in any stage of its development, from green to ripe.

The most common fruit rot in Michigan is gray mold (*Botrytis cinerea*) (Fig. 26). Gray mold is first noticed as a light brown, soft spot which soon spreads throughout the berry. The affected berry becomes dry and covered with a gray powder—the spores of the fungus. There is **no** distinct line between healthy and diseased fruit tissues. Rains, followed by temperatures near 65 degrees F. before and during harvest are required for outbreaks of this fruit rot. Gray mold also

may attack frosted or injured blossoms, fruit stalks, and leaves, turning them brown.

Until recently, *Dendrophoma obscurans* was thought to be a minor problem as a leaf blight fungus. It now has been associated with severe fruit losses as a stem-end rot. The fungus infects the sepal or cap as the blossom buds grow from the crown in the spring, turning them brown (Fig. 26). The infection progresses through the cap tissues; finally, near harvest time it reaches into the stem-end of the fruit causing the pulp of the berry to turn brown, soft, and watery (Fig. 26). There is a distinct line between good and diseased fruit tissues.

A common soil-borne fruit rot in Michigan plantings is *Rhizoctonia* brown rot. Infection starts where the ripening berry comes in contact with the soil. There a dry, spongy, dark brown to black rot slowly develops (Fig. 26) causing a one-sided berry, since the upper side grows normally while that in contact with the soil rots.

You can control fruit rots by using cultural practices and by spraying. You can reduce *Rhizoctonia* brown rot by mulching, thus keeping the berries from touching fungus-contaminated soil. A spray program as given in Extension Bulletin 154, Spraying Calendar will economically control gray mold and stem-end fruit rots.

One rot that may develop as berries are being shipped is "Leak", caused by the common black mold (*Rhizopus nigricans*). As the name implies, this fungus causes a collapse of the fruit with much loss of juice. The spores of black mold are common in the air and enter berries only through wounds. The rot develops rapidly above temperatures of 70 degrees F. You can reduce Leak by careful handling to prevent wounds, picking in the morning while the berries are cool, culling rotted berries, and holding the fruit at temperatures below 50 degrees F.

VIRUS DISEASES

Many plants of all strawberry varieties grown in Michigan are infected with one or more virus types. Field diagnosis is hard since clear-cut symptoms are usually absent. The presence of virus is found by grafting a suspected plant to a virus sensitive indicator plant, *Fragaria vesca* (Fig. 27).

The effect of viruses on runner plant and fruit production varies with the variety. **Catskill** is affected severely (Fig. 28), while **Robinson** and **Premier** seem to have a high degree of tolerance to virus infection.



Fig. 27. Wild European strawberry, *Fragaria vesca*, used as an indicator plant for viruses. Plant to the left is infected with virus; plant to the right is healthy.

For best results, obtain state-certified virus-free plants from one of the several cooperating Michigan nurseries.

Since strawberry viruses are transmitted in the field **only** by certain insects, follow the insecticide schedule in the Spraying Calendar, Extension Bulletin 154.



Fig. 28. The variety Catskill is affected severely by viruses. The row to the left is Catskill grown from virus-free nursery stock; row to the right was grown from regular nursery stock.

Two virus diseases which show good field symptoms are Leaf Roll and Witches Broom. Remove any plants with symptoms of these diseases. In addition, there are many other viruses which show no clear-cut symptoms.

Leaf Roll

Plants infected with leaf roll have long stems with small pale green leaves. The leaf margins are rolled **downward**, especially near the base. In severe cases, the leaves are rolled into a funnel-shaped tube. Plants with leaf roll are not stunted.

Witches Broom

Infected plants have multi-branched crowns with many short, spindly stems and small pale green leaves. Such plants have a "bushy" look. The runners also are so short that they root close to the mother plants, thus increasing the bushiness.

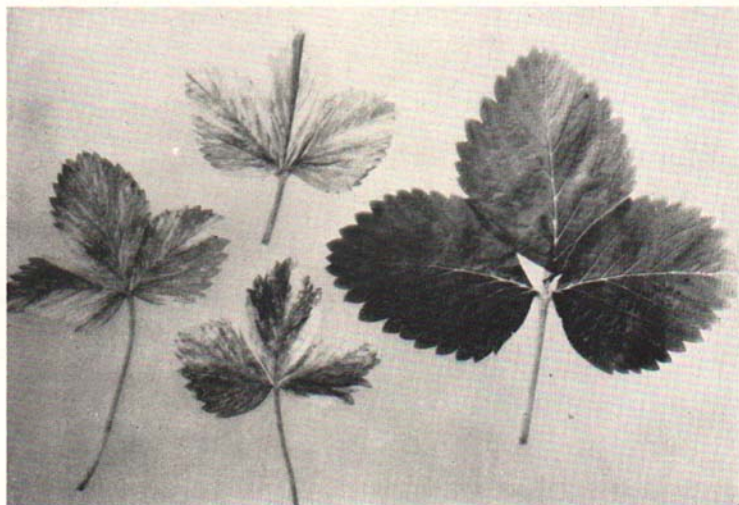


Fig. 29. Left - strawberry leaves showing symptoms of non-infectious variegation or June Yellows. Note the characteristic mottling with yellow and green. Right - healthy leaf.

Non-Infectious Variegation⁹

This disorder, also known as June Yellows or Blakemore Yellows, is not infectious.⁹ It is a hereditary character found in certain varieties as **Blakemore**, **Climax**, and **Premier**. The leaves are mottled and streaked with yellow or cream and green in the spring (Fig. 29). Symptoms of June Yellows are quite strong at temperatures below 50 degrees F., but disappear within 2 to 3 weeks as temperatures rise above 50 degrees F. Affected plants never recover and are less fruitful than healthy plants. All runner plants which grow from affected plants also have June Yellows.

⁹Non-infectious—not caused by bacteria, fungi, or virus.

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