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INTRODUCTION

The strawberry is the most popular of all small fruits. Its beauty, delicious flavor, and the fact that it ripens before other fresh fruits are available insure an active demand for the strawberry in all markets. In addition to its use as a dessert fruit, the strawberry is widely used for canning, for preserves, and as a flavoring for ices.

From the standpoint of the grower the strawberry has several advantages. It offers a source of cash in the early summer. The period of time between the setting of the plants and the first harvest is less than with other small fruits and much less than with tree fruits. The strawberry is adapted to culture in the garden under very intensive conditions or in the field where it can be given less detailed attention. It can be produced successfully on a wide variety of soils, under widely different climatic conditions, and it is attacked by comparatively few serious pests.

The strawberry is principally a crop for the small farmer. No expensive equipment is required for its culture. A large amount of work, especially that of harvesting, must be done with hand labor, and, therefore, the farmer with his family can care for a small planting of from one to three or four acres with very little cash outlay and comparatively little hired help.

Observations indicate widely different cultural practices among growers. There is an obvious need for more definite information concerning the relative value of different cultural practices and of other factors which are most influential in determining the success of the strawberry enterprise. The plan of this work has been to make a careful survey of the literature dealing with strawberry growing, to determine the methods which were followed by the more successful and less successful growers in order to ascertain, if possible, the significant differences in their programs, and, finally, to check the importance of these differences by field experiments.

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PART I. REVIEW OF LITERATURE

HISTORICAL

THE EUROPEAN STRAWBERRY

The strawberry *(Fragaria)* is a native of the temperate latitudes of both hemispheres. Native species are common in Europe, Asia, and in both North and South America. Even though both Virgil and Ovid refer to it, the early Greeks and Romans seem not to have grown it in gardens. According to the account given by Bailey in his Standard Cyclopedia of Horticulture, the earliest record of garden culture is the growing of the native wood strawberry, *Fragaria vesca*, in France early in the fourteenth century. In the fifteenth century wild plants were commonly transplanted into the English gardens where they were grown for their fruits.

Interest in the strawberry developed gradually and during the sixteenth century it is mentioned frequently in several herbals. By the latter part of the seventeenth century rather definite cultural practices were established and the strawberry was recognized as a desirable addition to the garden.

THE AMERICAN STRAWBERRY SPECIES

In North America the native strawberry was recognized to be of value by the early settlers and rapidly became popular. In the introduction to his book, "The Strawberry," Fraser (20) cites the following quotation:

> "Coming to more recent times, in 1629 William Wood, in writing of the attractions of the new land, says, 'There is likewise Strawberries in abundance, verie large ones, some being two inches about,' and in 1643 Roger Williams states, 'This berrie is the wonder of all the fruits growing naturally in all these parts'."

The North American strawberry, *F. virginiana*, was carried into European gardens early in the seventeenth century (30). The South American species, *F. chiloensis*, came into the picture only a little later, being introduced into French gardens early in the eighteenth century.

Nearly three quarters of a century later, in 1760, a Frenchman, Duchesne, published a book describing different sexes in strawberry flowers and he is supposed to have been the first to originate new sorts by crossing. The importance of this discovery was not appreciated for many years. In fact, as late as 1828 the idea was expressed in Loudon's Gardener's Magazine that the kind of strawberry makes little difference because the care and cultivation is responsible for quality and size of fruit.

It is obvious that the modern strawberry as we know it is of comparatively recent development. It is thought that the strawberry from which our modern varieties have been developed originated as a hybrid

of the two species, *F. virginiana* and *F. chiloensis*. The following statement appears in Bailey's Standard Cyclopedia of Horticulture (19):

> "The first of the modern race of large-fruited varieties was the Keens' Seedling, originated by Michael Keens, of England, in 1819; it was a Pine (either a form of *F. chiloensis* or a hybrid of that species with *F. virginiana*) and from it have sprung most of the European varieties of today. The Hovey, from which modern North American varieties have descended in large measure, was undoubtedly a Pine in part, but there is considerable evidence that one of its parents was a variety of *F. virginiana*."

Soon after the development of the Keen's Seedling variety another Englishman, Knight, produced successful crosses which gave varieties of great commercial value. By 1836 as many as 100 varieties were included in English catalogs and more than 200 varieties were listed by French nurserymen. Many of these English varieties were introduced into the United States, but the results were usually disappointing because the plants proved unsuited to this country. In 1834 an American nurseryman, Hovey, produced a seedling which he named the "Hovey." It was a cross between the large-fruited Pine strawberry from Europe and the hardy, vigorous, native species, *F. virginiana*. In discussing the importance of this development, Frazer says (20):

> "It was the sensation of the age with its large handsome fruits and by 1850 it had established the strawberry as one of the leading fruits in America, a position it has never lost."

The Hovey proved to be a pistillate variety and because the sex characters of strawberry flowers were not understood it was never really successful as a market variety. The real commercial development of the strawberry industry did not begin until the middle of last century. The opening sentence in Fletcher's "Strawberry Growing" (18) is as follows:

> "Commercial strawberry-growing in North America may be said to have begun with the introduction of the Wilson, in 1854."

RISE OF COMMERCIAL STRAWBERRY GROWING IN THE UNITED STATES

Following the introduction of the Wilson, in 1854, there was a feverish interest in strawberry growing and especially in the development of new varieties. From fewer than 1,500 acres at the time the Wilson was introduced the plantings increased to more than 150,000 acres before the close of the century.

Following this unusual expansion there was the inevitable reaction which resulted in a considerable reduction in acreage, but from 1850 to the present the general trend has been upward. The acreage devoted to strawberries in the United States at the close of the century in 1899 was reported as 151,373 (52). This was followed by a considerable decrease so that the average acreage for 1917, 1918, and 1919 was 85,670, (1) but since that time the industry has expanded so that the average acreage since 1930 has been approximately 180,000 (10). In 1934 the commercial strawberry crop in the United States ranked fifth in value among the fruit crops of the country (2).

Two factors have contributed largely to the spread of this industry. The plant has been found to be adapted to a wide variety of conditions.

In 1930 Strawbridge (45) made this statement:

> "The strawberry is adapted to practically all tilled sections of the United States. It is an early cash crop for each locality in which it is grown."

The second and perhaps the more important factor which has influenced the widespread distribution of the industry is the development of improved transportation, especially the development of refrigeration. In 1866 Earle began shipping strawberries from Cobden, Ill., in chests with ice, and by 1869 he had begun to ship in carloads with ice (3). In 1891 more than 600 refrigerator cars were used for fruits and vegetables and in 1929, 40,741 were used for fruits and vegetables, including 13,000 which were used for strawberries alone.

EUROPEAN CULTURE OF THE STRAWBERRY

GARDEN CULTURE AND FORCING

Strawberry culture in France and England has been on an intensive rather than an extensive scale since its beginning. In both of these countries the forcing of strawberries in greenhouses or specially constructed beds has remained very important until recent times. "The French Gardener," translated by Evelyn (16) in 1691, gives a good idea of the intensive methods employed:

> "The soyl (soil) which they most affect, is rather a sandy than a stiff, and therefore you shall make choice of that part in your garden for them, which most approaches this mixture."
>
> "To order them well, you must dress, weed and loose the mould about them very diligently, and to have fair and clear fruit, you shall stick a smaller prop to every plant, to which you shall bind their stalks with a straw."

Much the same recommendations appear prominently in periodical literature during the early part of the nineteenth century. In the early volumes of Loudon's Gardener's Magazine from 1826 to 1840 Knight and other writers favored the intensive culture but questioned the desirability of cutting all runners and stirring the beds in the fall. Great emphasis was placed on deep soil preparation and the liberal use of manure. There were frequent favorable references to the use of nitrate. The practice of allowing runners to set in matted beds, which were mowed and manured after picking and retained several years, was referred to by most writers as a careless, undesirable method which produced continuously smaller and poorer fruits.

Discussions of field culture first appeared in the Gardener's Chronicle about 1850. The hill system was used, and vegetable crops such as onions, spinach, and endive were suggested as intercrops. All writers agreed that a fertile soil was necessary but some recommended a sandy soil while others preferred a heavier type. The intensive methods of garden culture and forcing were reflected in the recommendations for field culture. In the first volume, 1872, of "The Garden" which was edited by Robinson, (48) the following statement is found:

> "Three main points to be observed in strawberry growing are digging deeply, planting early, and manuring heavily."

For both field and garden culture, late summer or fall setting was recommended. Either the plants which had been forced were used or the first runners were rooted in pots in the field. By these methods August setting was successful and good crops of fruit were harvested the following spring.

For many years during the last half of the nineteenth century there were comparatively few important changes in cultural recommendations. There was the usual discussion as to the proper time to apply mulch, the best season for setting, and the value of spring cultivation, but, nevertheless, there was general agreement.

About the beginning of the present century frequent references to overproduction began to appear in periodical literature. About 1907 it was reported in the "Gardener's Chronicle" that the transportation of strawberries from western England and from France was greatly hurting the greenhouse culture. Even though the production in France was concentrated near the cities and came from small plantings the crop was reported to be of considerable economic importance.

During this same period a great deal of discussion occurred concerning the deterioration or "running out" of varieties. Leaf spot and eelworms were considered the principal causes and growers were urged to introduce healthy, vigorous plants from other sections at least 100 miles distant. This introduction of fresh stock and greater care in cultural practices failed to stop the deterioration.

STRAWBERRY CULTURE IN THE UNITED STATES

INFLUENCE OF EUROPEAN METHODS

During the early period of strawberry growing in the United States, the cultural practices were patterned after English methods. Frequent references may be found in the magazines of that time to practices which closely resemble the forcing methods followed in England and France. The setting of pots in the fields in order to root the runners during the summer and thus provide potted plants for late summer or fall setting is an example of such practices.

In the early volumes of Hovey's Gardener's Magazine many systems of strawberry culture were discussed. Forcing, bed culture, row culture, hill culture, and, less frequently, the practice of allowing the plants to set runners forming more or less matted rows were given considerable attention. Thus, the discussion has continued until very recent times. Some writers have favored one plan and others have favored another. All of the time many growers have been successful with widely different methods, as was so strikingly expressed by Hovey, (24) 1861:

> "The strawberry is cultivated in a great variety of modes, viz. in rows, in hills, and in beds, some allowing the plants to bear only one crop, others two, and some three. Some mow the leaves after the crop is gathered; others turn in the old plants to make place for the new runners, and thus keep the beds on the same ground for several years. In either way, with good judgment and proper treatment, good crops may be produced; and under ordinary garden cultivation it is hardly possible, with a good soil and liberal manuring, to prevent a successful result, whatever may be the mode adopted."

THE EXTENSIVE SPREAD OF THE INDUSTRY RESULTED IN NEW METHODS

With the development of more extensive commercial strawberry growing there was a very definite tendency away from the more intensive methods of culture. Forcing and the culture of this fruit in beds have practically disappeared. Strong statements may be found concerning the relative value of the hill system and matted-row culture and often a modification of these, known as the hedge-row or the controlled-row, has been recommended. A careful study of recent literature leads to the conclusion that the matted-row plan has been generally adopted by commercial growers in most sections of the United States. The lower South and parts of the Northwest, however, have turned to the hill system.

SELECTION OF A SUITABLE SOIL

Soil Type

The selection of a suitable location for a strawberry planting has been recognized as a matter of great importance since the beginning of the industry. Among the factors which should be considered in the selection of a desirable site, the soil has been given the most attention. One of the early statements which described the characters of a good strawberry soil was made by William Prince (38). He said:

> "A light rich loam is considered the most favorable, being soft, and pliable so that runners may easily penetrate it with their roots."

One hundred years later a similar soil was described by Loree, (28)

> "Good crops of strawberries may be grown upon almost any type of soil, provided it is retentive of moisture, fairly fertile, and well drained."

During this century and up to the present similar statements have been very common, though some variations may be found.

Some writers favor a rather heavy type of soil, while others recommend a light texture but in almost all cases they agree that a high humus content is essential, that good drainage is necessary and that at least moderate fertility is very desirable.

The following summary statement by Fletcher (18) gives a fair explanation of these minor differences:

> "A survey of soil preferences in different parts of the continent discloses the fact that more strawberries are grown on a sandy loam underlaid with a clay than on any other soil type. The demand for early berries has had much to do with this choice. The most popular strawberry soil in the northern and central states is a gravelly loam with a clay subsoil. Heavy loams, silts, and light clays are preferred for late varieties in the East and are used very generally on the Pacific coast for all varieties."

"New ground" has been recommended frequently as most desirable for strawberries. That is probably because such land usually has abundant humus, is in good physical condition, and is comparatively free from serious weeds. In some sections growers have depended upon "new ground" for most of the strawberry acreage but usually such land has become scarce and it has been necessary to prepare old land for this crop.

Crop Rotation

No recommendations are found in recent literature for continuing strawberries on the same land for any great length of time. The accumulation of insects and diseases, the withdrawal of certain elements from the soil and the reduction of the humus supply, leading to soil erosion on even moderate slopes, are the usual reasons which are given for crop rotation. An almost endless variety of rotations are suggested by different writers, but certain recommendations are similar in nearly all references to this subject. Perhaps the most important of these is the use of some green manure crop, preferably a legume, in the rotation in order to maintain the humus supply.

The other important point upon which practically all writers agree is that strawberries should follow a clean cultivated crop in order to reduce the problem of weed control and the danger from insects, such as cutworms and white grubs which often accumulate in sod land. Irish potatoes, sweet potatoes, tomatoes, or other vegetables are considered suitable crops to precede strawberries.

Soil Acidity

Recently attention has been given to soil acidity as a factor in determining the suitability of a soil for strawberry growing. It has been recognized for many years that wild strawberries are found on soils which vary widely in this regard but that a slightly acid condition is most common. Morris, (33) working with strawberry plants growing in nutrient solutions, found that the limits were rather wide (pH_4 to pH_7, inclusive) but that best growth was produced in slightly acid solutions. The belief that successful strawberry production under ordinary conditions is not limited by the soil acidity is indicated by the following statement of Morris and Crist (12).

> "The reactions commonly found in so-called 'Agricultural' soils are probably *per se* not important limiting factors in strawberry production."

Aside from the selection of a suitable soil there seems to be practically complete agreement in regard to other characteristics of a good strawberry site. Both air and water drainage are considered necessary. Where early ripening is of great importance a southern exposure is usually suggested. Steep slopes which are subject to severe erosion are to be avoided.

SELECTION OF VARIETIES

A very large place in the literature of strawberry growing is occupied with discussions of varieties and the characteristics of desirable plants. The selection of suitable varieties is generally considered as fundamental to success with this fruit.

In 1861 Hovey stated in the columns of his "Gardener's Magazine" that the culture of the strawberry had not advanced during the preceding 10 or 15 years and gave the introduction of excessive numbers of inferior varieties as the principal reason. In 1917 Fletcher (18) indicated that the influence of these poor varieties was still apparent:

> "The Strawberry is burdened more heavily with indefinite and mediocre varieties than any other fruit."

During the time intervening between these statements, however, the aims of the strawberry breeders and the standards by which new varieties were judged changed very greatly. At the time Hovey wrote, during the strawberry boom, and for some time later, the chief interest was in the development of large-fruited varieties and in the study of flower characters. According to Darrow the interest of modern strawberry breeders is centered on quality, disease resistance, and the adaptability of the new variety to definite uses.

Two types of flowers are recognized, the pistillate and the hermaphrodite, but the hermaphrodite varieties which are grown today are very much more fertile than were those grown 75 years ago and are so desirable in other characters that they have largely replaced the pistillate kinds.

Since the introduction of the first of the "everbearing" varieties early in this century there has been some interest in their cultivation. They have not become of great commercial importance, owing probably to the fact that they require a more fertile soil and more careful attention. The everbearing varieties lack in runner production and therefore are less adapted to the matted-row system of culture.

SELECTION OF PLANTS FOR SETTING

The discussion concerning the type of plant which should be set has centered almost entirely about the size and age of runners. Field-grown plants are used and there is general agreement that old mother plants and those which have exhausted themselves by fruit production are not desirable. The following statement by Fletcher (18) summarizes the discussion on the selection of runner plants:

> "For many years it was the prevailing opinion that the first, second, and third runners are valuable for setting in the order named; that runners formed later than these, and especially alley plants, never should be used, even though of good size. ..... Later evidence has shown that tip plants of fair size start off better in the spring, and have fewer fruit buds than older plants, which is an advantage."

Later in the same paragraph he says:

> "It is likely that the vigor of the plant, particularly the strength of the root system, is more important than the time of year when it was produced."

Later writers, such as Barnett from Kansas, (6) agree with this statement.

Recently some attention has been given to so-called pedigree plants, those which have been grown from selected mother plants, but most writers agree that such plants are only slightly superior to others.

CULTURAL METHODS

With the spread of commercial strawberry growing and the development of extensive plantings many of the extreme practices associated with forcing and garden culture were found to be impractical and there was a tendency to question all of the old methods. The result of such attitudes was the development of all sorts of variations from what might be called a standard system. Some writers were inclined to

defend the old intensive methods but many turned to the other extreme and a great confusion resulted. Gradually, however, some practices have become standardized and generally accepted.

Methods of Setting

From the very early days of commercial strawberry growing to the present there has been practically complete agreement that great care should be exercised in the setting of the plants and the recommendations have changed very little. In "The Horticulturist," 1861, Fuller recommended that the roots be trimmed for spring planting but not for fall setting, and he suggested that setting be done on cloudy days to prevent drying of the plants during the planting. He emphasized especially that the roots be spread evenly, that the plants be set deeply but not deep enough to cover the crown, and that the soil be firmed carefully about the roots. The recommendations of recent writers on this subject are fairly represented by the following quotation from Auchter and Knapp (4):

> "Set the plants firmly, at the proper depth and when the soil is moist. Any planting method that takes account of these factors will give good results. ..... Set the crown at ground level. ..... If the roots are long and straggling, clip slightly to aid in planting."

Cultivation

Leading writers uniformly emphasized the importance of thorough soil preparation, that is, deep plowing followed by careful working. Though contradictory statements are found frequently concerning the comparative advantages of deep and shallow cultivation, there is almost complete agreement that strawberries respond to frequent, thorough tillage which controls weeds and grass during the growing season. Statements similar to the following may be found in most discussions of this subject.

> "Thorough cultivation during the first season cannot be too strongly urged. It conserves moisture, promotes the growth of plants, keeps the weeds down, and is in every way beneficial." (11)
>
> "Frequent and shallow tillage the first season is one of the secrets of successful berry growing." (35)
>
> "The old saying 'tillage is manure' holds true for strawberries." (46)

Life of a Commercial Plantation

Regarding the profitable life of a strawberry plantation, there is a wide difference of opinion. Some writers recommend that only one crop be harvested. The more common recommendation, however, is that two or possibly three crops may be taken from a planting. The plans which are suggested for the renovation of a strawberry field after the first crop vary greatly. A review of periodical literature indicates that many growers practice no cultivation between the first and second crop, but simply mow the weeds once or twice during the summer. Most of the leading writers recommend rather thorough working during the second summer. Such a thorough program may be outlined as follows: After the first harvest the tops are burned or mowed, the rows are narrowed with a plow or other cultivator, the plants are thinned in the row and grass or weeds are removed by hand.

Following this renovation the cultivation is continued throughout the summer as it was the first season. The exact method of renovation, in fact the decision as to whether a planting should be worked at all after harvest, will depend upon the conditions of that particular field.

Fertilization—Recommendations of Last Century

Regarding strawberry fertilization, the literature becomes hopelessly confusing and the writings of the last two decades are fully as contradictory as are those of the last century. Before the spread of extensive commercial strawberry growing it was the custom to incorporate large quantities of manure into the soil as it was being prepared. The practice was generally adopted for field culture but differences of opinion were common. Pardee (36) was among the first prominent writers to question the heavy fertilizing of this crop. In 1853 he said,

> "Almost everyone who cultivates strawberries, I notice, has fallen into two very great errors. First, of allowing different varieties to intermingle..... The other error, I observe, about as universally prevalent, is over feeding, and as a consequence, an over growth of vines and a deficiency of fruit..... Such highly enriched soils can be in a measure counterbalanced by liberal applications of potash, lime, and salt."

The next year Hovey took strong issue with this statement. In answer to Pardee he said:

> "This may be true, but so far as our experience goes—the experience of 25 years—we are sure that fine fruit of the largest size cannot be abundantly raised without a good soil well manured. ..... Whoever attempts to raise fine strawberries without manure (or its equivalent, guano) will signally fail." (25)

The idea that very fertile soils were not desirable for strawberries was widespread for several years but the following statement from a special committee report (43) presented before the Illinois Horticultural Society in 1877 indicates that by that time there had been a renewed interest in fertilization:

> "The theory formerly prevalent, that the soil should not be made rich for strawberries, has been generally practically abandoned by cultivators of this fruit."

A careful study of the literature dealing with strawberry fertilization, since the beginning of the century, shows two almost opposite schools of thought, those who do not believe that the application of fertilizing materials is profitable and those who recommend the rather liberal application of one or more elements. The most striking difference of opinion concerns the application of nitrogen. A few quotations are given in the following paragraphs representing the first of these groups.

Fertilization—Negative Evidence

Davis, (15) of the Central Experimental Farm, Ottawa, Canada, states:

> "One thing which stood out, however, was that the plants when set out were incapable of utilizing a readily available supply of nitrogen and in many instances nitrogen applied at that time resulted in injury to the newly set plants, even though the fertilizer did not actually come in contact with the foliage."

The effect of fertilizer on the carrying quality of strawberries in Alabama is reported by Kimbrough (27). He says,

> "Judged by their condition on arrival after being shipped by express or transported by automobile a distance of over two hundred miles, the carrying quality of berries from these plants (those made excessively vigorous by 400 pounds of nitrate of soda in the spring) was not as good as that of berries from less vigorous plants."

He continues to say,

> "Heavy applications of muriate of potash did not improve the carrying quality of strawberries.
>
> "It seems evident that fertilizer treatments may affect the carrying quality of berries, but the extent of this effect is probably not as great as has been thought."

The Kentucky Experiment Station (44) reports:

> "The results continued to show that a foundation treatment of the soil with lime and phosphate and the use of sweet clover as a rotation crop has made a very favorable condition for strawberry production. The addition of fertilizers containing nitrogen, phosphorus or potassium, either separately or in combination, has not increased the yield. The addition of nitrogenous fertilizers sharply reduced the yield in all cases this year."

Cochran and Webster, (9) of Oklahoma, report the effect of nitrogen as follows:

> "In all cases under field conditions where the application of nitrogen was high, fewer plants came through the dry season, with a smaller yield per plot."

Greve (22) has reported experiments concerning the effect of nitrogen on the growth and blooming of the Howard 17 strawberry in Maryland. In the report of this work he says:

> "In general, there is little indication that summer and autumn nitrogen applications were in any way either significantly beneficial or injurious under the not unusual conditions surrounding the experiments."

The foregoing findings seem sufficient to prove that the application of fertilizing materials to strawberries is of very doubtful value, that it may prove injurious and that it cannot be considered a profitable practice. The literature of this same period, however, is filled with information from equally reliable sources which is almost directly contradictory.

Fertilization—Positive Evidence

Among those who recommend liberal fertilization of the strawberry there is wide variation as to the best materials but most authorities agree that manure is beneficial. Many of those writers who recommend other materials emphasize the value of humus and very few of them offer any objection to manure. The statement by Shaw (41) from North Carolina expresses the opinion of many investigators of his time. He indicates a very definite preference for manure over the chemical fertilizers. After expressing this preference, however, he says:

> "As a rule, an abundance of nitrogen will produce heavy yields and large berries, but sufficient phosphoric acid and potash, in available forms are needed to develop the flavor, color, and firmness of the fruit.
>
> "The use of these fertilizers (chemical fertilizers) alone, without the addition of sufficient vegetable matter, will soon leave the land in an impoverished, unproductive condition."

During the last 15 or 20 years attention has shifted largely from manure to the commercial fertilizers. The comparative importance of different materials has been the subject of much discussion. In 1919 Mooers (31) presented a discussion of this subject before the Tennessee Horticultural Society. He reported that the evidence on the value of liming for strawberries indicated that application directly for strawberries was not likely to be profitable and might be detrimental. He said that there was clear evidence that strawberries were sensitive to deficiencies in phosphoric acid and recommended 400 pounds of superphosphate per acre as a reasonable application. Potash, on the other hand, was considered much less important and more than very light applications were discouraged.

Several years later, in 1930, Hoddy (23) reported to the same society that the strawberry growers in Blount county, Tennessee, had realized great profit from the application of potash to their fields in the spring.

The annual report (17) of the Arkansas Experiment Station is in general agreement with the statement of Mooers:

> "The results from fertilizer treatments on old strawberry fields for 1930 were not only inconsistent but contradictory. There were, however, indications of benefit from phosphorus and of injury from the use of too much nitrogen.
>
> "Accumulated evidence from previous seasons shows that on both heavy and light soils phosphorus from the standpoint of production is the most important fertilizer. Nitrogen is next in importance but there is danger of using too much at a single application. Potash is the least important, but it is necessary for maximum production on light soils."

Nitrogen is given much greater importance in comparison with the other materials by many writers. Loree (29) concluded that spring applications of nitrogen stimulated vigorous runner production while summer applications had little effect on runner production but favored crown development. He found no indication that fertilizer treatments had any effect on the moisture content, texture or quality of the fruit.

In the South, fall and early winter applications correspond, so far as their effect on plant growth is concerned, to spring applications in the northern sections. In 1932 Taylor, (47) of Alabama, made this statement:

> "In general, applications of nitrogenous fertilizer to strawberries in Alabama in the fall and early winter increased the numbers of flower clusters, flowers, and fruits."

Darrow and Waldo (14) found that the vegetative stimulation which resulted from applications of nitrogen, or from any other cause, tended to increase the amount of decay which occurred in the field. Nevertheless, regarding the important fertilizer applications they say,

> "Superphosphate was apparently somewhat more effective than potash in increasing the yield of fruit.
>
> "The use of nitrogen fertilizers is essential to the production of large yields of early berries in this secton."

Occasional references may be found to the profitable application of fertilizers to strawberries in the spring of the crop year. Such results are reported by Baker in Transactions of the Indiana Horticultural Society, 1932, (5) but there seems to be general agreement that ferti-

lizers intended to increase yields should be applied during the summer or fall of the preceding year. In this connection Loree (29) said:

> "Applications of fertilizers in the spring of the fruiting year have no effect on the number of clusters, or the number of flowers per cluster."

Shoemaker and Greve (42) found that spring applications of nitrogen, in Ohio, did not increase yields while applications in August of the preceding year made marked increases. Very similar results are reported by Tucker (51) in Virginia.

The effect of varying nutritive conditions both in the soil and in the plant at different seasons of the year were studied by Gardner (21) in Missouri. He said:

> "It is clear, however, that the nutrition question, as it relates to strawberries, is a late summer and fall question to a much greater extent than has been generally suspected, and that investigators and growers can well afford to give it consideration from this point of view."

Despite the inconsistent and contradictory results which have been reported from experimental tests, the application of fertilizers is a general practice among commercial growers in the leading strawberry states. So many other factors influence the yields and quality of berries that it is often difficult to determine the real effects of fertilizer treatments.

INSECTS AND DISEASES

Among the important fruit crops the strawberry suffers less from insects and diseases than most. A regular program of spraying has never been adopted by most of the growers in any commercial section because such cultural practices as careful plant selection, crop rotation, clean cultivation, and thorough sanitation have prevented or greatly reduced the losses from the common pests.

Probably the most generally distributed strawberry diseases are those which affect the leaves such as the leaf spots, scorch, leaf blight, mildew, yellows, and strawberry dwarf or "crimps." Except for the last two, commercial control has usually been obtained by the selection of resistant varieties and the careful burning of the old leaves after harvest. Strawberry yellows has been most serious on a comparatively new variety, Blakemore, and no control has been developed except the planting of disease-free plants well isolated from infected plantations. Strawberry dwarf or "crimps" is caused by a nematode, different from the one which causes root knot, and is controlled best by rather long rotations and careful rogueing.

The most serious strawberry root disease is one known as "Black Root." This disease usually first appears with hot weather and may cause the death of a considerable percentage of the plants during the summer.

Fruit rots of the strawberry, such as gray mold, leather rot, hard rot, and leak (Rhizopus), often cause heavy losses in the field, in transit, or in the market. The leather rot, hard rot, and even gray mold are usually more serious in the field and the losses correspond closely to the weather conditions. Warm rainy weather favors the spread of these diseases.

Among the insects attacking the strawberry, the crown borer, white grub, and weevil are the most serious. The leaf-roller and root louse

are widely distributed but usually are not of great economic importance. Under ordinary conditions crop rotation, careful sanitation, and the selection of plants make it possible to avoid serious losses.

ECONOMIC PROBLEMS OF IMPORTANCE

Yields

The popular strawberry literature between 1850 and 1875, while the industry was expanding so rapidly and spreading into new territories, contains comparatively few references to yields of less than 50 bushels per acre and most reports give yields ranging from 100 to 150 bushels per acre. The popular literature of more recent times indicates that the yields range from 50 to 100 24-quart crates per acre.

Labor Requirements

The labor required for the production of strawberries was given by Hutson (26) in Kentucky, 1924. The average for 63 growers was given as 111.8 man-hours for the first crop, 51.2 hours for the second crop, and 34.7 hours for the third. The number of horse-hours decreased in a similar way, averaging 65.7 hours for the first, 29.6 for the second, and 20.8 for the third crop. Concerning the importance of abundant labor he made this statement:

> "..... some farmers got about two crates of strawberries for each hour spent in cultivation, while others devoted almost two hours for each crate. This difference is due, to a great extent, to efficient and inefficient practices."

According to an Arkansas report the cost of producing, harvesting, and delivery for shipment in 24-quart crates was about eight cents per quart. The labor and farm power previous to harvest was said by the authors to range from 5 to 10 per cent of the total, while harvesting, packing, and delivery for shipment amounted to 50 per cent and the cost of the crates alone amounted to 15 per cent of the total cost (8).

The labor requirement for strawberry production under Maryland conditions in 1929 was given by Whitehouse, Hart, and Walker (53). In the Marion area about 12 cultivations and four hoeings were given during the first year and three cultivations with one mowing and raking, but no hoeing, was given the second season. For such a program the labor requirement was 186.6 man-hours and 66.9 horse-hours for the first year, and 18.0 man-hours and 15.0 horse-hours for the second year.

Cost of Production

The attempt to analyze the cost of producing strawberries, especially the distribution of the cost among the separate items, and an attempt to determine the profits which have been received by the producers of this crop is very unsatisfactory. General statements concerning the cost of production may be found scattered through the popular literature but very few actual data are available. In "The Horticulturist" (32) for 1849 a grower of Watervliet, Mich., reported a cost of $60 per acre. Pardee, (37) 1858, gave the cost of cultivation as $15 to $25 per acre. A grower near Wallingford, Conn., gave, (1867) in more detail, the costs of producing 9¼ acres of strawberries. A summary of this record, (40) on a per acre basis, is as follows:

Team work and labor	$90.46
Manures	44.92
Bog hay and straw mulch	40.86
Interest on capital, taxes	11.79
Total production costs	$188.03

Picking and marketing	$91.46
Freight, traveling, tel.	61.14
Commission	30.20
Team work	6.49
Wear of crates	13.51
Total marketing costs	$202.80

A much more detailed statement of production costs was given in the American Fruit Grower for February 1919. In this report (7) the expenses are given separately for the first and second years.

First Year	
Rent	$7.00
Taxes	1.80
Plowing	2.00
Harrowing	1.00
Marking	.15
Setting, four days	6.00
Plants and digging	1.50
Cultivating, seven times	3.00
Hoeing, cutting runners and blossoms	8.00
500 lbs. fertilizer	6.00
Sowing 1 bu. oats	1.20
200 crates, 16 qt.	24.00
Picking	40.00
Packing and hauling	10.00
Total	$111.65

Second Year	
Rent	$7.00
Taxes	1.80
Mowing	1.00
Rejuvenating	2.50
Cultivating, six times	3.00
Mulch	4.00
Mulch application	3.00
Mulch removing	1.50
100 crates	12.00
Picking	25.00
Packing and hauling	7.00
Total	$67.80

An examination of these data shows that approximately 65 per cent of the total cost was that for picking and handling the crop and between 50 per cent and 60 per cent of the production costs were required for labor.

It is not surprising that reported profits vary greatly because many factors influence both the cost of production and the returns. Most recent writers agree that the most important of these factors are associated with yields per acre and quality.

Factors Affecting Price

In addition to yield per acre, market price is important in determining profits. Five factors which affect strawberry prices are quality, quantity, condition which causes a variation in demand, the bargaining ability of growers' organizations, and the efficiency of the whole marketing system (49).

Since the early days of the extensive field culture of strawberries there have been repeated discussions of the danger of overproduction. As early as 1868 such discussions were common in the Rural New Yorker and other periodicals and again 20 years later considerable emphasis was being placed on the danger. As the industry has spread through widely separated sections and the transportation facilities have been greatly improved so that such a perishable crop can be put in distant markets successfully the matter of overproduction is an interstate problem. For example, the early Michigan crop competes with that from Ohio, Indiana, and Illinois, and its mid-season and late crop with that from Minnesota, Wisconsin, and New York.

PART II. FACTORS INFLUENCING PROFITS IN MODERN STRAWBERRY PRODUCTION

METHODS OF THE PRESENT STUDY

The strawberry is a rather intensive crop. It is planted, usually, by individual growers in small acreages and is produced at a comparatively high cost per acre. Large acreages are occasionally found in single plantings but in most instances the strawberry is a family crop and the acreage is limited to that which can be cared for by the family labor with additional help during harvest.

The strawberry crop, like all agricultural crops, follows rather regular cycles. There are periods of increased interest during which the acreage is rapidly expanded, followed by periods of decline. This study was begun in 1929 when conditions were comparatively favorable and has continued through the most difficult years of the depression.

PRODUCTION RECORDS OF REPRESENTATIVE GROWERS

The problem has been approached from two angles. First and major attention has been given to a study of the commercial practices and methods of production which have been well established and are widely accepted. Through the cooperation of county agricultural agents, vocational agricultural teachers and others, contact was made with strawberry growers and production records were obtained. These records show the methods employed, the labor distribution, and all important production costs. Some of the best and some of the most inferior, as well as some of the more average fields, were included and the work was continued during a six-year period from 1929 to 1934, inclusive. In all, 69 records were obtained and their average should present a fair picture of existing conditions.

DIRECT COMPARISONS IN FIELD PLOT TESTS

Supplementary to this study, experiments were planned and conducted to provide direct comparisons between different methods of cultivation, fertilization, and other important cultural practices. Several of these tests dealing with methods of cultivation and fertilization were conducted at the Michigan Agricultural Experiment Station and at other places in cooperation with interested growers. In this way the tests were placed on different soil types and under different conditions of soil fertility. All comparisons were performed in triplicate, unless otherwise noted, and were repeated during two or more growing seasons. Many phases of the problem have been included in this experimental program.

The usual statistics from the Bureau of Agricultural Economics, the Agricultural Census and similar reliable sources have been used in a brief discussion of the marketing problem.

COSTS WHICH DIRECTLY INFLUENCE PROFITS

There can be no argument that strawberry profits like those from any agricultural crop depend upon three main factors—namely, cost, yields, and selling price.

GENERAL DISTRIBUTION OF COSTS

The total cost involved in the production and harvesting of the first strawberry crop from a new planting, according to the average of 63 records, was $120.27. The average cost of the second crop against which no charge was assigned for establishing the plantation and for which the period of cultivation was shorter, was $77.90 per acre. (Table 1). Less intensive culture was given by most growers during the second year of the plantation's life. For the first crop nearly half of the total expense was incurred before the fruit was mature, while for the second crop three-fourths of the expense was incurred during the harvesting and handling of the fruit.

ANALYSIS OF PRODUCTION COSTS

An analysis of the items which comprise both the cost of production and the cost of handling the fruit is presented in Table 2. Labor constituted 51.2 per cent of the total during the first year and 40.6 per cent during the second year. During the first year in which the plantation was established the average cash outlay was $19.93 per acre, which was 35.8 per cent of the total production cost. An important reason for keeping a strawberry plantation for the second crop may be found in the greatly reduced cash expenditure. According to the average of 40 records only $3.77 in cash was required to produce the second crop of fruit. On the other hand, the overhead or fixed cost represented a much larger proportion of the total cost during the second year than during the first.

OVERHEAD OR FIXED COSTS

Land Use

The charge for land-use has been listed as rent and 10 per cent of the land value is charged. Each grower was asked to place a value on the land which was occupied by the strawberry planting according to the value of his entire farm in relation to conditions in the community. This value was discussed and checked with the local agricultural agent or vocational teacher in order to avoid large inconsistencies. As would be expected there was a wide variation, ranging from $25 per acre in some of the more isolated sections, where a comparatively poor ridge land was cleared and used for strawberries, to as much as $200 per acre in a few cases where strawberries were produced near large cities. The more common range was from $40 or $50 up to $100 and the average for all records was approximately $70 per acre. Probably these figures fairly represent the value of the land that is commonly used for commercial strawberry growing. Land rental, therefore, was an item of considerable significance since, according to Table 3, it

TABLE 1. *Cost Per Acre of Raising and Harvesting an Average Strawberry Crop.*

	Number of Records	Cost of Production		Harvesting and Handling		Total Cost
		Actual	Per cent of Total	Actual	Per cent of Total	
First Year	63	$55.73	46.3	$64.54	53.7	$120.27
Second Year	40	19.11	24.5	58.79	75.5	77.90

TABLE 2. *Distribution of Items in Cost of Production.*

	Number of Records	Yield Per Acre (Crates)	Labor Cost			Cash Expenses			Overhead			Total Cost	
			Per Acre	Per Crate	Per cent of Total	Per Acre	Per Crate	Per cent of Total	Per Acre	Per Crate	Per cent of Total	Per Acre	Per Crate
First Year	63	67	$28.53	42.6¢	51.2	$19.93	29.7¢	35.8	$7.27	10.8¢	13.0	$55.73	83.1¢
Second Year	40	61.2	7.77	12.6¢	40.6	3.77	6.2¢	19.8	7.57	12.4¢	39.6	19.11	31.2¢

TABLE 3. *Detailed Analysis of Production Costs Per Acre.*

Item	First Year	Second Year
Number of records	63*	40*
Total overhead charge	$7.27	$7.57
Rent	$6.61	$7.39
Per cent of overhead cost	90.9%	97.6%
Per cent of production costs	11.9%	38.6%
Equipment charge	$0.66	$0.18
Per cent of overhead cost	9.1%	2.4%
Per cent of production costs	1.2%	1.0%
Total cash expense	$19.93	$3.77
Plants	$10.98	
Per cent of cash expense	55.1%	
Per cent of production costs	19.7%	
Fertilizer cost	$5.83	$2.29
Per cent of cash expense	29.3%	60.8%
Per cent of production costs	10.4%	12.0%
Mulch	$3.12	$1.48
Per cent of cash expense	16.6%	39.2%
Per cent of production costs	5.6%	7.7%
Total labor cost	$28.53	$7.77
Establishing plantation or renovation	$10.90	$2.04
Per cent of labor cost	38.2%	26.2%
Per cent of production costs	19.6%	10.6%
Summer cultivation	$16.06	$5.10
Per cent of labor cost	56.3%	65.8%
Per cent of production costs	28.8%	26.7%
Spring care	$1.57	$0.63
Per cent of labor cost	5.5%	8.2%
Per cent of production costs	2.8%	3.3%
Total production costs	$55.72	$19.11

*A composite of all records obtained during a 5-year period.

represented 11.9 per cent of the total production cost for the first crop and 38.6 per cent of the production costs for the second crop.

EQUIPMENT DEPRECIATION

As an additional fixed cost some charge was necessary for the use of equipment. With the exception of a disk, which is used during the first preparation of the soil, the entire cultivation of a strawberry planting, is done by very durable and inexpensive tools. Most of the cultivation is done with one-horse cultivators and after careful consideration it was decided to charge one cent per horse-hour for equipment depreciation. As can be seen in Table 3, this represented a very small part of the total production cost and less than 10 per cent of the overhead.

CASH EXPENSES

The cash expenses involved in the production of strawberries are very important to the commercial grower. Since a large part of the labor is performed by the family and, therefore, does not require an outlay of money and since the fixed charges are usually even less tangible there is a tendency for the grower to consider the cash expenses somewhat more important than they really are.

Plants

The largest single item according to this study was the cost of plants which represented 55.1 per cent of the cash expenditure during the first year. There was considerable variation among the growers in this charge because many of them purchased their plants locally at a cost frequently running as low as $1.25 per thousand or used their own plants and recorded a similar charge. Other growers cooperating in this study purchased from distant plantsmen at prices ranging as high as $3.50 or $4.00 per thousand. Additional variation was caused by the fact that some growers set 8,000-10,000 plants per acre while others spaced the plants much more widely and set only 4,000-5,000 plants. In most cases the growers who purchased expensive plants spaced them more widely and placed them on a better quality of soil than the average. The average cost given in Table 3 is $10.98 per acre for plants and approximately one-third of the individual records show a charge within $2.00 of that amount.

Fertilizer

The second largest expense was for fertilizer, even though 23 per cent of the growers made no application during the first year and 5.5 per cent of the records for the second year show no fertilizer cost. The average expenditure by those growers who made an application during the first year was $7.49 per acre, and the average for those making an application during the second year was $5.08 an acre. Considering the average for all records, however, the first-year fertilizer cost approximated 30 per cent of the total cash expense and 10 per cent of the total production cost. The second year fertilizer cost represented 60 per cent of the total cash outlay and 12 per cent of the total cost of production for that year.

Mulch

A similar condition exists in regard to the use of mulch. Only 40 per cent of the growers cooperating in this study applied mulch for the first crop and only 25 per cent made an applicaton for the second crop. The average cost for those growers who made an application was approximately $7 per acre and was, therefore, a very significant part of the total cost of production.

LABOR REQUIREMENTS AND COSTS

The cost of farm labor varied considerably during the period of this study. The rate according to the average of all records was 14.1 cents per hour. During the first two years, 1929 and 1930, the usual charge was 20 cents per hour but during the most difficult years of the depression farm labor was available at a lower cost. A similar variation occurred in the cost of horse labor which showed an average of slightly more than eight cents. A considerable part of the hand labor which is performed on a strawberry plantation is done by boys and this has tended to reduce the average cost per hour. Although these rates are somewhat too low to represent general conditions they are the actual costs and will serve as well as any to bring out the relative costs of different operations.

In an analysis of the labor required for the production of strawberries it is convenient to separate the total amount into three parts. First of all there is the labor required for establishing a plantation or renovating it after the first crop; second, the labor required for cultivation and other care during the growing season, and, third, the labor required during the spring before harvest.

Establishing the Plantation

The different types of land used for strawberry growing cause rather wide variations in the expense necessary for soil preparation and the establishment of a plantation. On the whole, the labor required for preparation of the soil, setting, and other work connected with establishing a strawberry plantation represented nearly one-third of the total labor required for the first year. The hand labor of setting plants was the largest single item and represented 17.5 per cent of all labor before the first crop was harvested. The amount of time required for setting varied greatly according to the spacing of the plants and the care which was used in the work. Seventeen of the 63 records showed fewer than 20 hours and 18 of the records showed more than 35 hours per acre required for setting, leaving approximately one-half of the records showing intermediate amounts of time. The preparation of the soil was the principal work requiring horse labor and represented approximately one-half of the total amount required for the first year. Where it is the practice to harvest two crops from a strawberry planting, one-half of the labor used in the establishment of the plantation should properly be recorded against the second crop.

Field Culture from Setting to Harvest

The proper care of a strawberry planting is not well standardized. Many growers consider that it should be given very intensive care during both the first and second summer. Other growers favor intensive care during the first summer and comparatively little work after the first harvest, while still other growers do not practice intensive culture during either year. According to the production records which are available for the first year, 13 of the 63 growers hoed their planting more than five times, 23 hoed three times or fewer during the first season, and 27 hoed four or five times. There was a similar difference in the horse cultivation. Those who followed the more intensive methods cultivated their planting from eight to ten times during the season, while almost an equal number cultivated only three or four times. Some justification for these differences may be found in the kind of land which is set. If the strawberries are following a very intensively cultivated crop like potatoes the soil will be fairly free from weeds, will be in good condition, and will require less cultivation than if land is used which has been carelessly tilled or has been uncultivated. According to the available data, it requires an average of 19 hours hand labor each time the strawberry planting is hoed. Less time is required during the early season before runners start than during late summer when the matted row has become established. Practically all of the horse cultivation is done with one-horse implements, with two to five shovels, and on the average it requires about four hours per acre for each working.

Comparatively little labor is required in a strawberry planting during the spring before the first harvest if proper cultural practices were followed during the previous summer. Only 34 of the 63 records showed any hand work during the spring and only 28 reported horse labor. When the average time required for spring work is based on all the records it amounts to but 5.2 per cent of the total man labor requirement and 9.1 per cent of the total horse labor. Those growers who reported spring work, however, used an average of 15.7 man hours and 12.9 horse hours per acre which is a more significant factor in the total labor requirement. Some growers pull out the large weeds during the spring before harvest but no great amount of labor is used for such work.

The actual labor used in the care of a strawberry planting before the first harvest varied from a minimum of 67 hours per acre reported by one grower to a maximum of 285 hours reported by another. These extremes represent exceptional cases since only eight of the 63 records reported fewer than 100 hours and only 13 reported more than 200 hours per acre. The average, given in Table 4, fairly represents the labor requirement for satisfactory strawberry culture.

The care of a plantation after the first crop depends greatly upon the conditions which exist. Many growers who have given their planting only mediocre care during the first season do not find it profitable to continue the planting for a second crop. Some, also, allow the planting to remain without any care and harvest a second crop if prices are favorable and there is a sufficient quantity of fruit to justify picking. The production records which are available show these differences clearly. For example, only 24 out of 40 second-year records reported any definite plan of renovation. Only 33 of the 40 did any cultivation

TABLE 4. *Analysis of Labor Distribution. (On an Acre Basis.)*

First Year, 63 Records	Second Year, 40 Records
Establishing the plantation	Renovation
Man labor	Average based on all records
Setting (hrs.).....28.5—% of total.17.5	Man labor (hrs.)... 7.7—% of total...17.9
Other labor (hrs.).....20.7—% of total.12.7	Horse labor (hrs.).. 6.7—% of total...37.2
Total (hrs.).....49.2—% of total.30.2	Average based on records reporting (24)
Horse labor (hrs.).....33.0—% of total.51.6	Man hours.....12.8—Horse hours..10.5
After prorating labor	Summer care after first crop
Man labor (hrs.).....24.6—% of total.17.8	Average based on all records
Horse labor (hrs.).....16.5—% of total.34.8	Number times hoed 1.4—times plowed. 2.2
First summer labor	Man labor (hrs.)...32.5—% of total...75.5
Number times hoed... 4.2	Horse labor (hrs.)..10.3—% of total...57.2
Number times plowed. 6.1	Average based on records reporting (33)
Man labor (hrs.).....105 —% of total.64.5	Number times hoed 2.1—times plowed. 2.8
Horse labor (hrs.).....25.1—% of total.39.2	Man labor (hrs.)...39.3—Horse labor..12.2
Spring before first crop	Spring care before second crop
Man labor (hrs.)..... 8.4—% of total. 5.2	Average based on all records
Horse labor (hrs.)..... 5.8—% of total. 9.1	Man labor (hrs.)... 2.8—% of total... 6.7
Total labor	Horse labor (hrs.).. 1.0—% of total... 5.5
Man hours: Actual...162.6—prorated..138	Average based on records reporting
Horse hours: Actual.. 63.9—prorated.. 47.4	Man labor (hrs.)... 7.5—(15 records)
	Horse labor (hrs.).. 4.1—(8 records)
	Total labor
	Average based on all records
	Man labor: Actual.43 —prorated.....67.6
	Horse hrs.: Actual.18 —prorated.....34.5
	Average based on records reporting (35)
	Man hours.....49.1—Horse hours..20.7

after the first crop, and five of the 40 growers who reported on a second crop did no work of any kind after the first harvest. The averages presented for the second year in Table 4 may be misleading for those reasons. When averages are based upon all records they show only 7.7 man-hours and 6.7 horse-hours per acre to be required for renovation, while the 24 growers who did special renovation in their plantings reported an average of 12.8 man-hours and 10.5 horse-hours per acre. Even those growers who practice cultivation during the second summer follow less intensive methods than are customary during the first season. Seventeen of the 33 growers who reported cultivation hoed their planting one time or did not hoe at all but used horse cultivation entirely. Only four of the records showed more than three hoeings during the second summer. Approximately one-half of the records show that plowing was done three or four times, and only two report that plowing was done more than four times.

The totals which are given in Table 4 show that on the average only 26.8 per cent as much man labor and 28.1 per cent as much horse labor was actually used during the second year as during the first. After the labor of establishing the plantation has been divided, approximately half as much labor is charged against the second as against the first crop. It is clear, therefore, that when other conditions are reasonably favorable the opportunities to obtain a profit from the second crop are greater than from the first crop. This fact in large measure justifies the thorough intensive care of a strawberry plantation during the first year.

HARVESTING AND HANDLING COSTS

The strawberry is an extremely perishable crop and requires close attention during harvest. In order for the fruit to reach the consumer in desirable condition it must be picked as soon as it is entirely colored, it must be handled as little as possible and moved into the market in the least possible time. The cost per acre varies directly with the yield and is much less significant than the cost per crate. A separate tabulation of the harvesting and handling cost for the first and second crops showed no significant difference in the percentage of the total cost which was reported for the different items. For that reason all records are combined in Table 5 which gives the separate items in the harvesting and handling of this crop.

Packages

In this report all references to crates refer to 24-quart crates. The cost of these packages is a heavy expense to strawberry growers, representing 30 per cent of the total expenses for harvesting and handling the crop. The cost of crates has not varied as much as would be expected during the period of this study. The lowest price that was reported by any considerable number of growers was 26 cents and the highest price reported was 35 cents per crate. These packages are seldom returned for use the second time and in seasons when the price is low the difference between profit and loss may hinge upon the cost of packages.

Picking

The labor required for the handling of a strawberry crop is the largest item of expense. According to the data presented in Table 5 the labor cost was approximately 59 cents per crate, which represented 51.4 per cent of the total harvesting and handling cost. Picking strawberries is slow and expensive. Women and children are used a great deal and are generally found to be more satisfactory than men for this work. They are usually paid by the quart and the rate is practically uniform in each community. During the early years of the present study 2 or 2½ cents per quart was the customary rate, but during the worst years of the depression this was reduced to 1 cent per quart and in recent years it has generally been increased to only 1½ cents. Some of the large growers who employ large numbers of pickers make it a practice to hold back a fraction of the pay until the close of the season, giving it as a bonus to those pickers who remain with them throughout the entire season. Most growers with small acreages are able to do most of the picking with their own family and the help of neighbors. It is desirable to have a large proportion of the cost of harvesting and handling a strawberry crop remain in the family or in the immediate community. According to the data presented in Table 5, the cost of picking amounted to approximately half the total cost of harvesting and handling the crop and represented more than 75 per cent of the labor.

Table 5. *Harvesting and Handling Costs.*

Package Cost		Labor Cost				Hauling Cost	Total Cost
		Picking	Grading and Packing	Supervision	Total Labor		
Per Acre.....	$19.04	$30.03	$5.60	$2.66	$38.29	$4.98	$62.31
Per Crate.....	29.4¢	46.4¢	8.6¢	4.1¢	59.1¢	7.7¢	96.2¢
Per cent of Total..	30.6%	48.2%	9.0%	4.2%	61.4%	8.0%	

Number of records: 103. (63 for the first crop and 40 for the second crop.)
Yield per acre: 64.8. (67 for the first crop and 61.2 for the second crop.)

Growers with rather large acreages find it necessary to supervise the picking and packing carefully. Those who have a small acreage and are able to care for the work with their own family and the help of their neighbors do not employ additional help for this purpose. Only 65 of the 103 records gave a separate charge for supervision and the average cost according to these 65 records was $4.23 per acre. Seven large growers who had employed field bosses to supervise the picking reported a cost of $10 or more per acre for supervision.

Grading and Packing

The methods used in grading and packing strawberries differ greatly in different communities and also from year to year. During seasons when the supply is limited and the market demand is active growers find it unnecessary to practice as careful grading as is done during sea-

sons when there is a distinct surplus of fruit. Some growers practice uniform methods of grading in order to supply a uniform quality to their trade. These growers usually follow a definite plan as follows: as soon as the pickers deliver the fruit to the packing shed the packers take each cup and turn it into an empty cup so that all defective berries can be removed. The fruits in the top layer are then arranged in a uniform way to hide the calyx and to present a smooth uniform surface. The expense of such handling amounts to from 8 to 12 or possibly 15 cents per crate according to the condition of the crop. Most strawberry growers, however, simply rearrange the top berries and do not turn the cups at the packing shed. According to the average of more than 100 records included in this study, the cost of grading and packing was 8.6 cents per crate. This amounted to only 9 per cent of the total harvesting and handling cost, but represented 14.6 per cent of the labor.

Hauling

The cost of hauling fruit to the shipping point was not easily determined. In every community growers are scattered over a rather wide area and under such conditions the cost of hauling represented a significant proportion of the total cost. On the other hand, many growers located within a few miles of the shipping point delivered berries in passenger cars at little expense. Hauling charges were usually based on a per crate charge when the work was done by a truck hired for that purpose. In cases when the owner delivered his own berries to the shipping point a per mile charge was used varying according to the quantity of fruit which was delivered. The average charge of 7.7 cents per crate given in Table 5 is liberal, considering the conditions in most strawberry shipping communities. This charge represents 8 per cent of the total harvesting and handling cost.

FACTORS WHICH CONTROL STRAWBERRY YIELDS

The survey of literature which has been reported in Part I indicates clearly the wide difference of opinion among growers and writers as to the cultural methods which produce the highest yields of strawberries with the greatest profits. It is evident that there are many factors which contribute to the profitable production of this crop and the obtaining of high yields per acre. A summary has been prepared from a group of records on strawberry fields which were set in 1929. These records, in Table 6, are assembled in two groups according to the total yields. From a study of this tabulation some idea can be obtained of the relative importance of various factors which influence production. One of the most obvious relationships is that between the yield and land value. The average land value for the high-producing group is $94.16 and for the low-producing group it is only $58.33.

ADAPTABILITY OF THE SOIL

Among the many factors affecting the profitable production of the strawberry crop the soil is of first importance. Growers speak with considerable assurance that certain areas have a "strawberry soil" and other locations do not. Experience and observations make this fact

TABLE 6. *Association of High and Low Yields with Certain Cultural Factors.**

No. Grower	Crates Per Acre	Land Value	Soil Preparation Per Acre		Fertilizer Cost	Cultivation Per Acre		Date Last Cultivated	No. Cultivations	
			Man hrs.	Horse hrs.		Man hrs.	Horse hrs.		Hoe	Plow
10	108	$100	10	15	$6.00	82	15	8/14	4	6
29	90	100	15	30	.....	81	24	8/20	3	6
7	80	100	12	24	.....	109	21	8/21	4	5
27	82	100	29	42	13.00	84	20	?	2	5
28	87	100	33	24	.....	91	40	7/28	3	7
1	103	65	19	19	.....	150	48	10/1	4	9
AVERAGE	91.6	$94.16	19.6	25.6	$3.16	99.5	28	8/23	3.3	6.3
2	28	$100	5	12	.....	80	20	?	4	4
4	47	100	16	24	$9.00	81	12	7/10	3	4
5	44	50	8	16	9.50	131	17	8/17	4	4
6	36	40	30	30	5.60	62	14	7/14	3	6
8	60	35	30	30	4.00	46	14	6/14	2	4
9	52	25	10	20	4.42	41	17	7/29	3	5
AVERAGE	44.5	$58.33	16.5	22	$5.42	73.5	15.6	7/17	3.2	4.5

*Records of fields set 1929, arranged in two groups according to total yield the first season.

certain even though definite proof is difficult to obtain and strawberries are recognized as a crop which can be grown on a wide variety of soils. The characteristics which make a soil satisfactory for strawberry culture are many and varied. Each factor exerts its influence but no one or two factors completely determine the suitability of a given soil.

Characteristics of So-Called "Strawberry Land"

A very desirable strawberry soil may be described as a sandy or gravelly loam which is in good physical condition, contains abundant humus, is at least moderately fertile, and is well drained. The lighter types of soils are more easily worked, more responsive to care, and are generally preferred by successful growers. Because strawberries are frequently grown in newly cleared land which is naturally poor some growers believe that it is a poor land crop. Observations throughout this study and the expressed opinion of successful growers, however, indicate that satisfactory yields are very difficult to obtain on poor land. Most growers who use thin, unproductive soil consider "new ground" to be necessary and usually attempt to grow only one planting of strawberries on a single location. To be satisfactory, a strawberry soil must be well drained yet retentive of moisture because plants are easily injured by either a water-soaked condition or a definite lack of moisture in the soil. This is especially important as harvest approaches. It is desirable to have a subsoil slightly heavier than the top soil because such a condition tends to retain fertilizers and moisture but it is very important that the subsoil be sufficiently open to allow the penetration of strawberry roots and to permit normal drainage.

The many factors which go to make up a desirable soil for strawberry growing are interdependent. If any one is seriously deficient it may become the limiting factor and practically prevent successful culture. When the factors are well balanced the most satisfactory yields are obtained with reasonable effort. Nevertheless, observations have led to the conclusion that the physical condition of the soil and the previous care which it has had are of the greatest importance. For the most part, strawberries are produced by the matted-row system of culture, and thorough cultivation is difficult after many runners have become established. If the soil has been poorly managed in previous years so that it is infested with weeds of various kinds the successful growing of this crop is difficult indeed. It is for this reason that successful growers prefer to plant strawberries following a clean-cultivated crop. Observations during this study have indicated repeatedly that low yields and unsatisfactory results usually follow the planting of strawberries on weed-fouled land.

Inspection Before Planting as a Guide

In order to obtain evidence on the importance of the soil in determining strawberry yields the soil was rated or scored by the writer in the fields which were included in Table 6. The rating of the soil was given at the time the planting was made and was based upon the factors previously discussed. In Table 7 those fields having more desirable soil are separated from the ones which had less desirable soil, and sufficient data are included to indicate the care which the fields had before the first harvest. In most cases, though not in all, the land

TABLE 7. *Effect of Desirable Soil on Yields.*

More Desirable Soil.*

Record No.	Land Value	Soil Preparation Per Acre		Fertilizer Cost	Cultivation Labor Per Acre		No. Cultivations		Date Last Cultivated	Crates Per Acre
		Man hrs.	Horse hrs.		Man hrs.	Horse hrs.	Hoe	Plow		
10	$100	10	15	$6.00	82	15	4	6	8/14	108
1	65	19	19	.....	150	48	4	9	10/1	103
28	100	33	24	.....	91	40	3	7	7/28	87
7	100	12	24	.....	109	21	4	5	8/21	80
4	100	16	24	9.00	81	12	3	4	7/10	47
29	100	15	30	.....	81	24	3	6	8/20	90
AVERAGE	$94.10	17.5	22.7	$2.50**	99	26.7	3.5	6.1	8/14	85.8
Less Desirable Soil*										
27	$100	29	42	$13.00	84	20	2	5	?	82
8	35	30	30	4.00	46	14	2	4	6/14	60
9	25	10	20	4.42	41	17	3	5	7/29	52
5	50	8	16	9.50	131	17	4	4	8/17	44
6	40	30	30	5.60	62	14	3	6	7/14	36
2	100	5	12	.....	80	20	4	4	?	28
AVERAGE	$58.33	18.7	25	$6.09***	74	17	3	4.66	7/17	50.3

(Records of Fields set 1929)

*Judged by inspection at the time of setting and giving due consideration to the factors discussed on pages 29 and 31.
**Average $7.50 for those including fertilizer.
***Average $7.30 for those including fertilizer.

which was given a high valuation by the owner was rated as satisfactory for strawberry growing by the writer even though the land valuation was not considered in the scoring. The fields in both groups were given practically the same care in preparation, but the group on the more desirable soil was given somewhat more careful cultivation during the season and cultivation was continued later in the summer. No doubt this additional care had some influence on the yields but it is not sufficient to account for all the difference. It is significant that five of the six growers having less desirable soil applied fertilizers while only two of those in the group having more desirable soil made such applications. Except in one instance, the soils judged to be more satisfactory produced high yields in comparison with those considered less desirable. The low yield for Record 4 may be explained by notes which were taken during the growing season showing that the land was worked while a little wet during soil preparation and only about 60 per cent of a stand was obtained at setting. Notes that were made in the fall indicate that later cultivation was very desirable but that some vacant places did not fill properly with plants.

The importance of a good soil was clearly indicated during the field experimental work conducted in this investigation. In 1932 cultural plots were established in three locations. All three of these plantings were on soil of similar type, being of dolomitic origin, but one of the soils had been worn out with long cropping so that it was less fertile, contained less humus, and was inclined to be more impervious to moisture than the others. One of the three soils had been very carefully managed during previous years and an alfalfa sod was turned during the early fall in preparation for a spring planting of strawberries. This soil was in excellent physical condition, was distinctly more fertile, and would be considered more desirable in every way than the first. The third planting was made on a soil intermediate in condition. It was less impoverished than the first but was distinctly less fertile than the second. Similar field tests were conducted on all three locations and the average yield which was secured reflected the original condition of the soil. The poor soil averaged 73 crates, the most fertile soil averaged 163 crates, and the intermediate one produced 92 crates per acre. Many similar observations have been made during the course of this investigation.

Importance of Available Phosphoric Acid

An attempt was made to obtain more specific evidence by collecting and testing samples of the soil from the fields where records were being kept. The available supply of phosphoric acid and nitrogen was determined by the method described in Michigan Agricultural Experiment Station Technical Bulletin 132. The acidity was determined by the LaMotte test and the humus content was determined by burning a sample of soil to constant weight.

All of the soils included in the survey were distinctly acid in reaction. The approximate pH value ranged from 4.9 to 6.2 but no significant relation could be found between acidity and yields. The only consistent data obtained in this study were on the importance of phosphoric acid. Soil samples were obtained for testing from 52 fields from which production records were available. Seventeen of these soils showed 75 pounds or more of available phosphoric acid per acre. Eight, or 47

per cent of these soils, came from fields which produced more than the average yield, 67 crates per acre. Twenty of the soils tested 50 pounds available phosphoric acid and nine, or 45 per cent of these samples came from fields producing yields above the average. Of the 15 soils which tested 25 pounds of available phosphoric acid or less only three, or 20 per cent came from fields where high yields were obtained. Among the fields producing yields above the average there were 20 which were tested for available phosphoric acid and of these 15 per cent showed 25 pounds or less, 45 per cent showed 50 pounds, and 40 per cent showed 75 pounds or more of available phosphoric acid.

A group of 22 records from fields which were set in 1932, in one county, were included in this study. Ten of these fields produced a yield above the average (62 crates) for the group and only one of these showed 25 pounds or less of available phosphoric acid, four showed 50 pounds, and five showed 75 pounds. Of the 12 fields which produced yields less than the average only two showed 75 pounds of available phosphoric acid or more and six showed 25 pounds or less.

To obtain additional evidence, soil samples were collected again in 1934 from fields where labor records were not available but from which yield records could be obtained. Forty-six of these tests were made and the average yield per acre for those fields was 81.6 crates. The data concerning acidity and the available nitrogen supply were equally as inconsistent as in the previous study. Nineteen of these fields produced yields above the average and 79 per cent of these high yielding fields showed 75 pounds or more of available phosphoric acid, while only 51.6 per cent of the 27 fields producing yields below the average showed this high amount of available phosphoric acid. Twenty-five records with the Aroma variety are included in this study and ten of these fields produced yields above the average (79.9 crates per acre). Only two of these ten fields had less than 50 pounds of available phosphoric acid per acre.

Though not conclusive, these results do indicate the importance of phosphoric acid in strawberry soils.

Throughout the studies inconsistent results could frequently be explained by notes which were made during the growing season. Many times the low yield in a field which showed favorable amounts of phosphoric acid was explained by poor cultivation, a poor stand of plants, or failure to harvest the entire crop. On the other hand, high yields from fields where the soil did not show a favorable amount of available phosphoric acid could frequently be explained by the unusually good care which was given during cultivation and harvesting.

Influence of Previous Care

In this study some indication was found that humus is an important factor in strawberry soils but no significant data were obtained. One group of treatments were intended to reduce the humus. For this purpose a series of three plots were kept free of all growth during the entire season and in another series of plots corn was grown with careful cultivation. Another group of treatments were planned to add organic matter to the soil without nitrogen and for this purpose weeds were allowed to grow without control in one series of plots, and sudan grass was seeded in another series. A third group of treatments were

TABLE 8. *Effect of Soil Treatment on Humus Content of Soil, Total Yield and Size of Fruit of the First Crop.*

Treatment	Per cent Humus in Soil at Harvest	Runners Produced	Average Yield	Average Total No. Berries	Per cent of Berries Diameter, in inches		
					¾ –	¾ – 1¼	1¼ +
Clean Cultivation	4.92	125	8.72	170	16.8	71.7	11.5
Weeds	4.93	136	10.80	207	12.2	70.7	17.1
Manure and Weeds	5.12	188	13.72	242	11.7	67.6	20.1
Peat and Weeds	5.78	131	13.86	262	14.3	68.7	17.0
Legume, Peas and Soybeans	5.13	153	12.16	255	11.4	74.1	14.5
Sudan Grass	5.12	91	9.88	192	14.7	70.3	15.0
Corn Cultivation	5.03	123	8.31	155	14.4	71.1	84.3

NOTE:—Figures are averages for plots run in triplicate, 20 plants to the plot, set 18 inches apart each way, with barrier rows between plots.

planned to add both nitrogen and humus to the soil. For this purpose an application of 10 tons of manure was made in the spring and another application of 10 tons was made in the fall to a series of three plots, and in another series a spring crop of peas was turned under followed by a summer crop of soy beans which was turned under in the fall. To the final series German peat was applied at the rate of 10 tons per acre. In the spring of 1932 strawberries were set in these plots and the plants were confined to the hill system. The production of runners recorded frequently during the growing season serves as an index of comparative vigor. Table 8 shows the results of this test at the first crop which was produced in 1933. The humus content of the soil was influenced only slightly by its treatment during the previous summer. The yield both in weight, in number of berries and in size of fruits corresponded rather closely to the soil condition which was improved by the addition of humus.

There is sufficient evidence available to justify the statement that success in strawberry growing is greatly influenced by the selection of a suitable soil and the management of that soil before strawberries are planted in such a way as to avoid serious weeds, and to maintain it in desirable physical condition and fertility.

METHOD OF CULTIVATION

Amount and Thoroughness of Cultivation

A study of Table 6 shows that cultivation is a factor which greatly influences strawberry yields. In Table 9 the same group of records are rearranged to include those receiving the largest amount of cultivation in one group and those receiving less cultivation in a second group. It will be seen immediately that there is a striking similarity in the two arrangements. In fact, only one field, Record 29, dropped into the lower group in the rearrangement and was replaced by Record 28. If the separation were based upon the number of cultivations given rather than upon the labor applied there would be comparatively little change. Record 29 would be returned to the higher group and Record 6 would replace Record 27 in this group. The date of the last cultivation may be even more significant than the total number of cultivations which are given in strawberry fields. This information is available in 10 of the 12 records which are included in Table 6. When the records are arranged on this basis all of those in which cultivation was continued late into the summer, except one, Record 5, are included in the high yielding group, and only one in which cultivation was stopped in July is included in this group.

To obtain more direct comparisons and more reliable data, field tests were arranged to determine the influence of efficient cultivation on strawberry yields. The Aroma, Premier, and Klondyke varieties, respectively, were used in these tests. Each test was run in triplicate with three record rows in each plot and a guard row between the plots. Clean cultivation was practiced in all plots during the early summer and was continued in one series throughout the summer and early fall. This cultivation was sufficiently frequent and intensive to control weeds and to keep the soil in reasonably good condition. In one series no cultivation was practiced after August 1, and in the third group of plots only horse cultivation was continued after that time because the matted

TABLE 9. *Effect of the Number of Cultivations on Yields.*

No. Grower	Crates Per Acre	Cultivations		Land Value	Soil Preparation Per Acre		Fertilizer Cost	Cultivation Per Acre		Date Last Cultivated
		Hoe	Plow		Man hrs.	Horse hrs.		Man hrs.	Horse hrs.	
1	103	4	9	$65	19	19	.....	150	48	10/1
10	108	4	6	100	10	15	$6.00	82	15	8/14
28	87	3	7	100	23	24	.....	91	40	7/28
29	90	3	6	100	15	30	.....	81	24	8/20
7	80	4	5	100	12	24	.....	109	21	8/21
6	36	3	6	40	30	30	5.60	62	14	7/14
AVERAGE	84	3.5	6.5	$84.17	19.8	23.7	$1.93	95.8	27	8/19
2	28	4	4	$100	5	12	.....	80	20	?
5	44	4	4	50	8	16	$9.50	131	17	8/17
9	52	3	5	25	10	20	4.42	41	17	7/29
27	82	2	5	100	29	42	13.00	84	20	?
4	47	3	4	100	16	24	9.00	81	12	7/10
8	60	2	4	35	30	30	4.00	46	14	6/14
AVERAGE	52.1	3	4.3	$68.33	16.3	24	$6.65	77.2	16.7	7/20

Records of Klondyke fields set 1929.

times. The other half was cultivated only four times and hoed five times. Probably the care which was given the second half was somewhat too good for the best test because the soil was so free of weeds and was in such good condition that at no time did any part of the planting really suffer. At the time of the first harvest there was very little difference in the total amount of labor which had been given the two areas. The difference amounted to only 20 man-hours and 5 horse-hours per acre. There was an increased yield, however, of 23 crates per acre in the part of the field which had been given most care.

The conditions in the second test were different. The weed problem made cultivation much more important. The more carefully cultivated area was cultivated six times and hoed seven times. The other area was cultivated five times and hoed six times, which was more cultivation than is done by the average strawberry grower. Nevertheless, tillage was made expensive when it was neglected until the weeds were well established. As a result, the part which was given fewer cultivations required 20 hours more man labor before the first harvest and only 4 hours fewer horse labor than did the area which was cultivated more times so that the work was done more effectively. The influence of this neglect was evident in the yields because there was a difference of 30 crates per acre in favor of the more intensive cultivation.

During the course of this investigation field tests have been conducted to obtain more direct comparisons on the importance of cultivation and its influence on strawberry yields.

A test planting was made in 1933 to obtain more accurate information corresponding to the trials previously described. The test was performed in triplicate with four rows in each plot and a guard row separating adjoining plots. Results of this test are presented in Table 11. This test was conducted on a red dolomitic soil which was of moderate fertility, in reasonably good condition, but somewhat deficient in humus. Previous care of the area had not controlled the weeds as perfectly as is desirable for a strawberry planting. The results corresponded closely to those reported from the commercial trials already described. The difference in total labor is not so great as would be indicated by the number of cultivations because of the additional work which was necessary after a period of neglect. That part of the planting which was given careless culture was not neglected more seriously than a large percentage of those of commercial strawberry growers. It was neglected sufficiently, however, to permit definite competition with weeds and the result was a greatly reduced stand of plants and some injury to the plants when the weeds were cleaned out. Even the neglected area produced 40 crates per acre which was above the yield of many commercial growers following the dry summer of 1933. The summary given in Table 11 shows a great increase in cost per crate when neglect results in seriously reduced yields. The results of these tests justify a strong statement that the timeliness of cultivation is of great significance in the production of reasonable yields at a reasonable cost.

Depth of Cultivation

Observations throughout this study have indicated a wide variation in the methods of cultivation which are practiced by commercial growers. In most instances tools which stir the soil deeply are used even

TABLE 11. *Relation of Thoroughness of Cultivation to Yield and Labor Cost.*

Treatment	No. Cultivations		Total Labor Per Acre		Labor Cost		Average			Summary		
	Hoe	Plow	Man Hours	Horse Hours	Total	Per Crate	No. Plants	Total Plot Yield	Per cent Below ¾ Inch	Yield 100 Plants	Per cent Below ¾ Inch	Crates Acre
								Pounds		Pounds		
Very Careful Culture	9	13	234	72	$54.00	55.9¢	2505	77.3	2.69	3.08	3.4	96.62
Careless Culture	5	6	200	48	44.80	$1.12	1442	32.0	1.01	2.21	3.1	40.00

Plots are four rows (1/45 acre) each, Aroma set 1933.
Labor—man hours 20¢, horse hours 10¢.

during comparatively dry seasons and on soils where surface cultivation is common with other farm crops. This observation raised the question as to whether strawberry yields are improved by shallow or deep cultivation, and in order to obtain evidence on this point additional field tests were planned.

The yield records from those tests show that there is comparatively little difference between the medium and deep cultivation and, that, except in one test, the yield was less with shallow than with medium cultivation.

The labor records in all of those tests show that there was no significant difference in the labor required by the different methods. As a result of those tests it must be concluded that strawberries differ from many farm crops in their cultural requirements, and that they are not injured by cultivation of medium or considerable depth. During the season of 1932 a brief study was made of the distribution of strawberry roots and it was found that they do not spread widely but are inclined to turn down and penetrate the soil to a considerable depth. Such a root distribution is not disturbed by cultivation, and whenever the soil becomes hard it will be improved by deep stirring. Growers are, therefore, not unwise in their selection of tools with from two to five shovels which stir the soil to a considerable depth. However, good judgment should be used in each planting and the depth of cultivation should be varied according to the conditions.

Cultivation After the First Crop

The problem of strawberry cultivation during the second season, after the first harvest, has been the subject of much discussion. Many growers who practice rather careful, intensive cultivation during the first season believe that it is unprofitable to attempt any cultivation after the first crop. They simply allow their fields to remain without attention during the summer, and in early fall or before harvest the second spring they mow the large weeds and remove them to avoid interference with the picking. Such practices are common but have been generally condemned by writers on this subject. Other growers practice very haphazard methods of cultivation following the first harvest and never approach the thorough work of the first growing season. They may work the planting thoroughly after harvest by way of renovation and then give only scant additional attention, or they may not practice intensive renovation but cultivate occasionally during the second growing season. There are many growers, however, who believe that cultivation is as important during the second as during the first season and they practice intensive methods of renovation followed by thorough cultivation until fall.

The influence of local and seasonal conditions makes it difficult to obtain reliable data on which to base an opinion concerning the cultural practices which are advisable during the second year. In Table 12 a group of 15 records are listed in the order of their yields at the second harvest and the amount of labor following the first crop is presented. The effect of cultivation is shown fairly clear in this table. All of the fields where no cultivation was given following the first crop are in the low-producing group and only two fields where a considerable amount of cultivation was done are included in this group. One of these, Record 69, was a piece of foul land where the weed prob-

TABLE 12. *Effect of Cultivation After Harvest on Second Year Yields.*

Record No.	Yield Crates	No. Cultivations		Total Labor Per Acre	
		Hoe	Plow	Man-Hours	Horse-Hours
65	124	2	3	43	16
66	104	3	4	28	14
67	98	2	2	20	15
55	75	3	4	79	16
45	49	1	4	36	16
58	48	1	3	44	18
51	40	3	5	112	12
*68	30	4	6	72	30
59	28	.....	.....	.....	.....
43	26	.....	.....	.....	.....
69	22	3	4	56	24
46	20	3	4	75	16
57	20	.....	.....	.....	.....
47	11	1	3	32	12
44	5	.....	.....	.....	.....

Fields of Aroma set in 1932.
*68.....Estimated that more than 1/3 of fruit was lost in field as overripes and, therefore, more truly belongs in higher group.
46 and 47.....No systematic renovation.

lem was very serious and cultivation was often delayed until the weeds had done serious injury. Records 46 and 47, which show some cultivation and yet are included in the group producing very low yields, were from fields where no systematic renovation was practiced but where occasional cultivation was given during the season. An attempt to arrange similar tables with other groups of records proved less successful. There was so much variation in cultural practices and such wide differences in yields that it was difficult to group them in any logical way. Considering the entire group of 40 records for which information is available during the second growing season there is certainly some evidence that cultivation does produce larger yields but that the expense per crate may frequently be increased to such an extent as to reduce profits.

To obtain direct comparisons, field tests have been conducted during this investigation to show the value of cultivation during the second year. The results of several such tests are presented in Table 13. Several important observations can be made from this table. First of all it is clear that cultivation after harvest greatly reduces the number of plants which are available for the second crop. The amount of the reduction depends upon the soil and weather conditions during the growing season, and in some cases the reduction may be so great as to reduce the total yield of fruit at the second harvest. However, in every case there was a significant increase in the yield per plant of the plants remaining after cultivation. Furthermore, in every instance except one there was a distinct increase in the proportion of fruits above minimum size for the U. S. No. 1 grade.

The amount of labor which was used in these plots equalled that usually required during the first growing season. The delayed renova-

TABLE 13. *Effect of Cultivation Following Harvest on Second Season Yields.*

Treatment	No. Plants	Plot Yield Pounds	Per cent Below ¾ Inch	Yield Per 100 Plants	Crates Per Acre	Date of Renovation	Total Labor Per Acre		Labor Cost	
							Man-Hours	Horse-Hours	Acre	Crate
No Cultivation After Harvest										
Test 1	.....	11.15	11.8	.....	18.6	.....	11.0*	.....	$2.20	11.8¢
Test 2	.....	12.74	17.4	.....	20.7	.....	6.7*	.....	1.34	6.4¢
Test 3	792	17.30	13.6	2.18	28.8	.....	41.0*	.....	8.20	28.7¢
Test 4	1944	81.57	28.7	4.09	135.8	.....	12.0*	.....	2.40	1.8¢
Test 5	1694	27.10	.....	1.60	67.7	.....	.....	.....	.....	.....
Test 6	2420	36.25	8.5	1.49	90.6	.....	4.0	.....	.80	.9¢
AVERAGE	1712.5	31.02	16.0	2.34	60.4	.....	14.9	.....	$2.99	9.9¢
Renovation Soon After Harvest with Later Cultivation										
Test 1	.....	21.55	8.9	.....	35.9	7/3	96.4	31.0	$22.38	62.3¢
Test 2	.....	5.87	15.3	.....	19.8	6/17	154.7	50.7	36.01	$1.82
Test 3	978	86.76	14.0	8.71	144.6	6/22	144.2	63.2	35.16	24.2¢
Test 4	1678	78.89	18.8	4.52	126.4	6/5	151.2	48.0	35.04	27.7¢
Test 5	789	28.55	.....	3.62	71.4	6/14	54.4	40.6	14.94	20.9¢
Test 6	1626	10.24	4.3	3.70	150.6	6/14	170.3	84.3	42.49	28.2¢
AVERAGE	1268	46.98	12.3	5.14	89.8	6/17	128.5	53.0	$31.00	25.2¢**
Renovation Delayed										
Test 4	979	46.81	17.4	4.78	77.8	8/7	171.2	55.0	$39.74	51.1¢
Test 5	579	31.59	.....	5.44	79.0	8/18	66.4	50.1	18.29	23.0¢
Test 6	861	47.77	5.55	4.40	119.4	8/8	123.0	53.0	29.90	25.0¢
AVERAGE	806.3	42.06	11.5	4.87	92.1	8/11	120.2	52.7	$29.31	33.0¢

All tests have 3-row plots except Test 5.
*Applying fertilizer, mulch, pulling big weeds, etc.
**Tests 1 and 2 omitted from the average. Dry season caused almost complete crop failure.
1—Set 1930, Aroma
2—Set 1930, Klondyke
3—Set 1931, Klondyke
4—Set 1932, Klondyke
5—Set 1932, Aroma (poor soil) 2-row plots
6—Set 1932, Aroma

tion, which is frequently practiced by growers, did not result in labor saving because of the large amount of hand work required to put the field in reasonably good condition after the weeds had become well established. From these results it seems clear that under normal conditions cultivation will increase definitely the amount of fruit which is produced at the second harvest when such cultivation does not seriously reduce the stand of plants and that the size of the fruit will be improved by such cultivation. However, these gains may not compensate for the increased labor cost per crate. In Tests 1 and 2 in which rather intensive cultivation was given following the first crop unfavorable weather conditions reduced the yield to such a point that the cost per crate was excessive and the work was definitely not profitable. The following note was made near the close of the growing season concerning the second test reported in this table:

> "The season of 1931 following renovation was excessively dry and practically no new plants were formed in plots where thorough renovation was practiced and no serious weeds or grass developed in the uncultivated plots."

Intensive renovation of a strawberry field may be accomplished in different ways. Many growers prefer the following plan: as soon as possible after harvest the plants are mowed and the tops are raked from the field. The middles between the rows which have been packed by the pickers during harvest are cultivated in order to destroy weeds and to loosen the soil on the surface. A few days later the rows are barred off with the turning plow, leaving them from 8 to 12 inches wide and covering all plants and weeds between the rows. The narrow rows which remain are then hoed or chopped in such a way as to remove weeds and thin the strawberry plants. After this has been done the middles are cultivated carefully and dirt is thrown back to the row or slightly over the row in order to add fresh dirt about the crowns of the plants which remain. Frequently a turning plow is used so that the row is covered and then the dirt is leveled with a harrow until the strawberry plants begin to show.

A less intensive method of renovation is recommended by many growers, especially in seasons when the soil is not in good condition to work. By this plan the rows are not barred off but the middles are carefully cultivated with a double shovel or three-foot cultivator. The work is continued until the soil has been thoroughly pulverized and weeds or strawberry runners have been destroyed. Then the strawberry row itself is cleaned out by hand with a hoe. By this method the row is not reduced in width and the plants are not thinned so severely as they are by the more intensive plan.

To obtain some evidence as to which method is the more desirable, tests were conducted during 1932 and 1933. The results of these tests, reported in Table 14, indicate that more plants are available for the second crop following the less intensive method of renovation, but that the increased yields per plant largely balance this so that the yield per acre is not greatly affected. The large amount of hand work required for cleaning out the row without barring off makes the total labor cost as much or slightly more than when the more intensive practices are followed. The conclusion reached is that the method of renovation is of comparatively little importance so long as the work

TABLE 14. *Costs of Renovation Methods and Their Influence on Yields.*

	No. Plants	Plot Yields Pounds	Per cent Below ¾ Inch	Yield Per 100 Plants	Crates Per Acre	Renovation Labor Per Acre		Labor Cost	
						Man-Hours	Horse-Hours	Acre	Crate
Intensive Renovation with the Rows Barred-off									
Test 1	978	86.76	14.0	8.71	144.6	41.1	20.1	$10.29	7.1¢
Test 2	1524	57.98	19.9	3.80	96.6	42.0	37.2	12.12	12.5¢
Test 3	814	37.71	.....	4.63	95.4	25.3	27.5	7.81	8.2¢
Test 4	1626	60.24	4.3	3.70	150.6	39.0	34.2	11.22	7.5¢
AVERAGE	1235	60.67	12.7	5.21	121.8	36.8	29.9	$10.36	8.8¢
Less Intensive Renovation without Barring-off									
Test 1	1031	91.99	14.6	8.92	153.3	35.5	7.5	$7.85	5.1¢
Test 2	1904	63.42	24.2	3.33	105.7	39.0	27.6	10.56	10.0¢
Test 3	817	20.67	.....	2.03	51.7	30.7	15.2	7.66	14.5¢
Test 4	2335	60.62	5.7	2.59	151.6	39.5	26.7	10.57	6.9¢
AVERAGE	1522	59.17	14.8	4.22	115.6	36.2	19.3	$9.16	9.1¢

Labor charged 20¢ man hours and 10¢ horse hours.
1—Renovation, 1932, Klondyke.
2—Renovation, 1933, Klondyke.
3—Renovation 1933, Aroma (poor soil).
4—Renovation 1933, Aroma (good soil).

TABLE 15. *Effect of Fertilizer Application on Yields and Returns. Fields of Klondyke Set 1929.*

No. Grower	Crates	Fertilizer Cost	Land Value	Soil Preparation Hours Per Acre		Cultivation Hours Per Acre		Date Last Cultivation	No. Cultivations		Total Costs	Net Returns	Profits
				Man	Horse	Man	Horse		Hoe	Plow			
2	90	.....	$100	15	30	81	24	8/20	3	6	$35.79	$141.30	$105.51
3	80	.....	100	12	24	109	21	8/21	4	5	51.85	85.65	33.80
5	87	.....	100	33	24	91	40	7/28	3	7	40.54	108.21	67.67
6	103	.....	65	19	19	150	48	10/1	4	9	54.45	165.43	110.98
7	28	.....	100	5	12	80	20	?	4	4	29.46	49.61	20.15
AVERAGE	77.6	.....	$93	16.8	21.8	102.2	30.6	8/26	3.6	6.2	$42.42	$110.04	$67.62
11	60	$4.00	$35	30	30	46	14	6/14	2	4	$38.44	$106.20	$67.76
12	52	4.42	25	10	20	41	17	7/29	3	5	21.27	101.01	79.74
10	36	5.60	40	30	30	62	14	7/14	3	6	37.29	59.32	22.03
1	108	6.00	100	10	15	82	15	8/14	4	6	34.34	220.27	185.93
8	47	9.00	100	16	24	81	12	7/10	3	4	49.71	44.01	−5.70
9	44	9.50	50	8	16	131	17	8/17	4	4	41.22	55.30	14.08
4	82	13.00	100	29	42	84	20	?	2	5	44.95	180.80	135.85
AVERAGE	61.3	$7.36	$64.28	19	25.3	75.3	15.6	7/24	3	4.9	$38.17	$109.56	$71.38

is thoroughly done and therefore the method should be adjusted according to the soil conditions and the stand of plants.

FERTILIZATION

Among the 69 field records which were included in this investigation 49 included a charge for fertilizer during the first year and 15 of the 40 records for the second crop included a charge for that item. Fertilizer averaged 45 per cent of the total cash expense and 11.2 per cent of total production cost during the two years. Some of the most successful growers consider the strawberry to be a crop which does not require liberal fertilization while others believe in the application of comparatively large quantities of fertilizers.

When the records are classified according to the application of fertilizer, as is done for a group of 12 plots in Table 15, it appears that this factor is of secondary importance in the production of high yields. Only one unfertilized field of those listed failed to produce a high yield, and only two fields which were fertilized produced a yield above the average. This distribution of records gives additional emphasis to the importance of cultivation which has been previously discussed. From these, representative of others that might be included, it appears that the fertilization practices now followed by commercial strawberry growers are not giving consistent results; consequently a series of field tests were conducted to obtain additional information on this phase of strawberry production.

Nitrogen Applications

General observations and a study of the production records indicated clearly that nitrogen was considered the most important fertilizing material by commercial strawberry growers. First attention, therefore, was given to the investigation of results which may be obtained from applications of nitrate of soda. In Table 16 the effect of applications at setting and during the first growing season are presented from four different tests. All of these tests were run in triplicate and the averages of each trial are presented in the table. Test 1 was conducted on a comparatively poor soil which had been out of cultivation for two or three years. The yields from individual plots in this trial were less consistent than would be expected, and the value of nitrate of soda was not clearly indicated. Trial 2 was conducted with the Premier variety on the farm of a commercial grower. The conditions for this test appeared to be unusually favorable; there were no apparent variations in the soil, and all plots started to grow uniformly. Observations during the growing season did not show any marked difference in the vigor of plants or in the color of foliage according to the fertilizer treatments. In this test, as in Trial 1, there was as much variation among plots with the same application as between different treatments, and there was no consistent evidence that applications of nitrate of soda were effective. Trial 3 was conducted on a moderately good soil and Trial 4 on poor land a few miles distant. The area for both of these tests appeared relatively uniform and a good stand of plants was obtained at setting in both tests.

No difference in plant vigor or foliage, either color or size, could be observed during the growing season or in the spring before harvest. The detailed yield records for Test 4 are somewhat more consistent

TABLE 16. *Effect of Nitrate of Soda Applications on a New Planting During the Growing Season.*

Treatment	Test 1		Test 2		Test 3		Test 4			Average		
	Runners 7/15	Plot Yield	Runners 7/16	Plot Yield	Runners 7/11	Plot Yield	Runners 7/28	Plot Yield	Yield 100 Plants	Runners by Late July	Plot Yield	Crates Per Acre
150 lb. Nitrate at Setting	247	74.04	187	105.61	.....	.....	490	97.63	5.50	308	92.43	154.1
75 lb. Nitrate at Setting and in June	260	78.11	203	109.80	270	69.28	565	105.43	4.95	324	98.88	164.8
50 lb. Setting, 50 lb. June, 50 lb. Sept	251	72.23	231	104.66	297	83.43	471	106.23	5.74	312	99.96	166.6
No Nitrate	229	76.74	182	106.26	293	80.07	361	80.34	5.64	266	93.66	156.1
75 lb. June, 75 lb. Sept	236	70.01	201	106.86	265	70.57	419	85.20	5.16	280	90.72	151.2
150 lb. Nitrate Sept	223	64.15	210	98.56	.....	.....	463	85.90	4.95	299	82.87	138.12

1. Aroma.....3-row plots—first crop 1931.
2. Premier.....3-row plots—first crop 1931.
3. Aroma.....2-row plots—first crop 1931.
4. Aroma.....Poor soil—3-row plots—first crop 1933.

Crates per acre are based on Tests 1, 2, and 4, inclusive.

than for either of the others and apparently the value of nitrate is indicated. In this test the number of plants was counted before harvest so that the yield per 100 plants could be calculated. These counts indicate that the advantage resulted from the production of more plants rather than an increase in production per plant. During July the number of runners which had been produced before that time was counted. These counts indicate that the number of plants may be somewhat increased by the application of nitrate of soda during the first year but that the increase is not sufficient under most conditions to result in a significant increase in yield per acre.

In Table 17 six trials are presented showing the results of applications about the time growth was starting in early March. These trials represent a wide variety of conditions such as is found among strawberry fields. All trials were conducted in triplicate and the detailed yield records show considerably more consistency than was reported for the applications during the first summer. Field observations following these applications did not reveal increased plant growth except in Trial 4 where a darker green color and possibly increased vigor was observed.

In Trials 2 and 5 an application of 300 pounds of nitrate of soda was included. In Trial 2 this increased application produced an average yield of 16.84 pounds and in Trial 5, 21.44 pounds per row. These yields are practically the same as those produced by applications of 150 pounds per acre and in both cases are less than those produced where no spring application was made.

TABLE 17. *Effect of Spring Application of Nitrate of Soda on Yield.*

	No Nitrogen	March 1 150 lb. Nitrate of Soda
Trial 1—Plot Yield	118.16	124.78
Trial 2—Row Yield	18.64	16.38
Trial 3—Row Yield	7.84	7.51
Per cent below ¾ inch	25.6	26.5
Trial 4—Row Yield	14.07	16.70
Yield 100 Plants	3.28	3.68
Trial 5—Row Yield	22.34	21.41
Yield 100 Plants	7.67	6.88
Per cent below ¾ inch	7.4	6.9
Trial 6—Row Yield	22.45	22.14
Yield 100 Plants	6.29	5.41
Per cent below ¾ inch	2.14	2.75
AVERAGE—		
Row Yield	33.91 (16.27)	34.82 (15.10)
Yield 100 Plants	6.98	6.14
Per cent below ¾ inch	18.1	20.3
Crates per Acre	169.6	174.1

1—1932, Premier.....2nd crop.
2—1932, Aroma.....2nd crop.
3—1932, Aroma.....2nd crop.
4—1934, Aroma.....2nd crop, poor soil.
5—1933, Aroma.....3rd crop.
6—1935, Aroma.....2nd crop.
Average row yields in ( ) based on Tests 2, 3, and 5 only.

TABLE 18. *Effect of Time of Spring Application of Nitrate of Soda on Yield.*

	150 lb. Nitrate of Soda Feb. 1	75 lb. Nitrate Feb. 1, Mar. 1	No Nitrogen	50 lb. Nitrate Feb. 1, Mar. 1 and May 1	50 lb. Nitrate Mar. 1, Apr. 1 and May 1
Trial 1—Plot Yield	98.50	89.63	106.26	79.76	90.31
Trial 2—Plot Yield	70.89	72.83	76.74	74.74	76.16
Trial 3—Yield 100 Plants	4.78	5.06	5.64	5.26	5.50
Plot Yield	72.23	70.96	80.34	77.96	105.36
Trial 4—Plot Yield	114.78	101.83	106.98	103.81	117.70
Trial 5—Plot Yield	10.44	12.24	12.00	13.52	12.55
Per cent below ¾ inch	9.9	7.7	7.5	8.7	10.02
Trial 6—Row Yield	11.56	11.52	13.28	13.26	8.91
Per cent below ¾ inch	18.7	19.6	14.9	17.0	20.7
Average 1st Crop					
Plot Yield	80.54	77.81	87.78	77.49	90.61
Crates per Acre	134.4	129.7	146.3	129.2	151.0
Average 2nd Crop					
Row Yield	19.54	17.94	18.89	18.65	19.88
Yield below ¾ inch	14.3	13.6	11.2	12.8	15.3
Crates per Acre	97.7	89.7	94.1	93.1	99.4
Final Average					
Crates per Acre	116.0	109.7	120.2	111.1	125.2

1—1931, Premier, 1st crop.
2—1931, Aroma, 1st crop.
3—1933, Aroma (poor soil) 1st crop.
4—1932, Premier, 2nd crop.
5—1932, Aroma, 2nd crop.
6—1933, Aroma (single rows).
Average yield for 2nd crop is given on basis of single row.

The effect of nitrate of soda in the spring before harvest was tested by varying the time of application; the results are presented in Table 18. In Trial 3 which was conducted on very poor land the influence of spring applications appeared in the darker green of the leaves and a noticeable increase in plant vigor. Trial 6, however, which was conducted on good land did not show such a response, and at the beginning of harvest it was not possible to pick out those rows to which nitrate had been applied. There is a slight indication in these results that applications of nitrate of soda before the second crop produce more favorable results than similar applications before the first crop. In 1933 an application was made preceding the third harvest on a planting of Aroma. The result of this test strengthens the suggestion that old plantings are more likely to profit from spring applications than are young plantings. No appreciable difference resulted from the application of this material as a single treatment or divided into two or three smaller applications. The only possible conclusion from these tests is that spring applications of nitrate of soda have failed to produce significant increases in yield.

The problem of obtaining satisfactory yields from the second crop is difficult to solve, and the practice of applying fertilizers after harvest in order to increase them is general among growers who practice cultivation following the first harvest. Some growers who do not practice cultivation make applications of fertilizers either during the second summer or in the spring before the second crop. Five trials to determine the value of applications of nitrate of soda after harvest are

TABLE 19. *Effect of Applications of Nitrate of Soda After Harvest on Second Year Production.*

Treatment	Test 1	Test 2		Test 3		Test 4			Test 5		Average			
	Plot Yield	Per cent Below ¾ Inch	Plot Yield	Per cent Below ¾ Inch	Plot Yield	Per cent Below ¾ Inch	Plot Yield	Yield 100 Plants	Yield 100 Plants	Row Yield	Per cent Below ¾ Inch	Yield 100 Plants	Row Yield	Crates Per Acre
150 lb. Nitrate at Renovation	130.06	6.5	19.29	14.8	25.50	8.5	34.28	6.13	3.05	11.73	9.9	4.59	16.99	84.6
No Nitrogen	106.98	6.4	14.59	15.3	21.23	7.2	31.81	5.15	2.94	11.84	9.6	4.04	14.34	71.7
150 lb. Nitrate Sept. 1	101.63	7.9	15.29	19.2	24.07	7.7	41.51	6.15	3.46	12.58	11.6	4.80	15.00	75.0

1—Harvest 1932, Premier.....2nd crop, 3-row plots.
2—Harvest 1932, Aroma.....2nd crop. 3-row plots.
3—Harvest 1932, Aroma.....2nd crop, 2-row plots.
4—Harvest 1933, Aroma.....3rd crop, 2-row plots.
5—Harvest 1934, Aroma.....2nd crop, single row, poor soil.

presented in Table 19. In every case except Trial 5, which was seriously injured by a very dry growing season following the 1933 harvest, the effect of nitrate of soda applied at the time of renovation is indicated distinctly. The exceedingly dry summer following the 1931 crop almost caused the failure in the plots of Trial 2, but despite these conditions the influence of nitrogen can be seen. The soil was in reasonably good condition for cultivation at the time renovation was done and the application was made but there was very little rain following that date and plant growth was very much suppressed. The conditions for renovation in Trial 5 were very much less satisfactory. There had been no rain during harvest and the soil was very hard and dry when renovation was attempted. There were rains during late fall, however, which stimulated plant growth and resulted in reasonable yields. The different soil conditions at the time of renovation and fertilization probably explain the response in Trial 2 and the lack of response in Trial 5. The influence of nitrate applied in September is less marked than that of applications made at renovation.

During this investigation an attempt was made to compare applications of sulphate of ammonia with nitrate of soda. In three of the four tests slightly lower yields resulted from the use of sulphate of ammonia, but the difference was not significant. Cottonseed meal as a source of nitrogen was used on two occasions during this experimental work, but in neither case did yields vary appreciably from those where nitrate of soda was applied.

Observations have been made repeatedly during these investigations concerning the effect of nitrogen applications on the carrying quality of strawberries. All of these observations indicate that applications of nitrogen during the spring tend to cause somewhat softer fruit during seasons of abundant rainfall. On June 8, 1932, eight boxes of Aroma berries were taken at random from each series of plots where spring applications of nitrogen were being compared. These were placed in a standard crate and sent approximately 200 miles by express without refrigeration. They arrived and were examined late in the afternoon of the following day. The boxes in the sample from plots where 300 pounds of nitrate of soda had been applied were entirely unsalable. Those from plots where no spring nitrogen had been applied were in fair condition and would be considered reasonably salable. The sample from plots receiving 150 pounds of nitrate of soda were intermediate in condition. Counts were made to determine the percentage of berries which were soft and it was found that 65 per cent were soft where 300 pounds of nitrate had been applied, 40 per cent in the sample from the rows receiving 150 pounds, and 14 per cent from the plots where no nitrogen had been used. It was observed, however, that the berries were of smaller size in the sample from the nitrogen-free plots and that in all cases the larger fruits were softest. A similar shipment of Premier strawberries was made from plots comparing applications of nitrate of soda and sulphate of ammonia. This shipment arrived with equal promptness and was examined immediately. The first observation indicated that Premier did not stand shipment as well as did the Aroma. All samples in this shipment appeared unsalable because of the crushed and injured fruits. Counts were made, nevertheless, and 31 per cent of the fruits were sufficiently firm to

hold their shape and be salable in the sample from plots where no nitrogen had been applied, 21 per cent from the plots where nitrate of soda had been applied, and 24 per cent from the sulphate plots. There seems to be clear evidence that nitrate of soda when it is applied in the spring before harvest tends to increase the possibility of damage during shipment.

Non-nitrogenous Fertilizers

Because of the rather unsatisfactory evidence obtained from the study on nitrate of soda as a fertilizing material for strawberries and the evidence which has been presented previously that soils suitable for strawberry growing should have a reasonable amount of available phosphoric acid, trials were planned during the seasons of 1934, '35, and '36 to determine the value of other forms of commercial fertilizer. The influence of applications of phosphoric acid and potash is presented in Table 20. Seven different trials are reported in this table but only two, Trials 1 and 4, were on distinctly poor soils and Trials 2 and 6 were on soils considerably better than the average. It will be observed

Table 20. *Effect of Fertilization at Setting on Yields.*

	16% Super-phosphate 400 lb.	Muriate of Potash 100 lb.	16% Super-phosphate 400 lb. Muriate of Potash 100 lb.	No Fertilizer
	Pounds	Pounds	Pounds	Pounds
Trial 1—Row Yield	9.35	10.48	11.26	8.58
Per cent below ¾ inch				
Yield 100 Plants	3.96	4.14	3.86	4.47
Trial 2—Row Yield	12.51	14.35	11.82	16.06
Per cent below ¾ inch	3.7	3.4	2.6	3.5
Yield 100 Plants	3.47	2.98	2.78	3.30
Trial 3—Row Yield	21.89	25.56	28.02	22.84
Per cent below ¾ inch	20.1	19.5	19.4	17.7
Yield 100 Plants	4.76	4.53	3.58	5.56
Trial 4—Row Yield	39.01	34.85	40.38	37.32
Per cent below ¾ inch	2.2	2.8	2.3	2.6
Yield 100 Plants	4.03	4.17	3.85	4.66
Trial 5—Row Yield	34.41	25.95	23.19	27.21
Per cent below ¾ inch	17.7	15.2	14.9	17.8
Yield 100 Plants	3.80	3.82	4.25	4.33
Trial 6—Row Yield	26.84	23.20	23.39	19.49
Per cent below ¾ inch	2.9	2.7	2.9	3.4
Yield 100 Plants	2.85	3.65	3.81	3.71
Trial 7—Row Yield	5.92	5.09	5.42	6.26
Per cent below ¾ inch	19.2	17.4	19.9	21.9
Yield 100 Plants	.45	.35	.45	.51
Average—				
Row Yield	21.42	19.92	20.50	19.68
Per cent below ¾ inch	10.9	10.1	10.3	11.1
Yield 100 Plants	3.33	3.78	3.23	3.79
Crates per Acre	107.1	99.6	102.5	98.4

All yields are for the first crop.
1—Set 1933, Aroma, poor soil.
2—Set 1933, Aroma.
3—Set 1934, Blakemore.
4—Set 1934, Aroma, sandy soil.
5—Set 1934, Klondyke.
6—Set 1934, Aroma.
7—Set 1935, Aroma, good soil (late freeze)

TABLE 21. *Effect of Fertilization at Renovation on Yields.*

Treatment	Trial 1			(1) Trial 2			(2) Trial 3			Average			
	Row Yield	Per cent Below ¾ Inch	Yield 100 Plants	Row Yield	Per cent Below ¾ Inch	Yield 100 Plants	Row Yield	Per cent Below ¾ Inch	Yield 100 Plants	Row Yield	Per cent Below ¾ Inch	Yield 100 Plants	Crates Per Acre
	Pounds		Pounds	Pounds		Pounds	Pounds		Pounds	Pounds		Pounds	
P_2O_5—450 lb	30.51	2.17	5.40	36.45	3.62	3.29	40.46	19.8	4.92	35.81	8.53	4.54	179.1
K_2O—100 lb	25.43	2.33	4.96	36.88	3.92	3.36	40.16	18.1	4.46	34.16	6.03	4.26	170.8
P_2O_5—450 lb.; K_2O—100 lb	25.40	2.22	5.70	39.21	3.24	3.00	39.08	19.3	4.67	34.56	6.43	4.46	172.8
No Fertilizer	32.83	2.54	5.17	35.12	3.42	3.01	40.17	20.8	4.52	36.04	6.93	4.23	180.2
P_2O_5—450 lb.; K_2O—100 lb.; Nitrate 100 lb	33.48	1.74	5.09	35.70	2.99	3.15	46.34	17.7	5.19	38.51	5.90	4.48	192.6
Nitrate—100 lb	35.63	3.08	5.23	42.09	2.93	3.12	45.44	16.1	4.99	41.05	7.37	4.45	205.3

(1) Application to single rows repeated 4 times with 12 no fertilizer rows.
(2) Application to single rows repeated 6 times with 18 no fertilizer rows.
1—1935, Aroma.....2nd crop.
2—1935, Aroma.....3rd crop.
3—1935, Klondyke.....3rd crop.

from this table that in three of the seven trials applications of potash increased yields and in four of the seven trials applications of phosphoric acid increased yields.

In 1936 a planting which included several varieties was available. Three rows of each variety in this planting were given applications of phosphoric acid and potash, and three alternate rows were not. These tests were on a soil much above the average in fertility and in no case did the applications of these materials produce a significant increase in yield. As a phase of this investigation, applications of phosphoric acid and potash were made in the row under the bed at the time of setting and also, in a furrow at the side of the plant immediately after setting. This was done in order to determine whether the placing of the material would have a significant effect upon the results. All applications in Trial 7 reported in Table 20 were duplicated in this way but in no case was there a significant difference in yields, according to the method of placing the fertilizer. The increased yields which follow applications of these materials on poor soils seem to be due partly to the increased number of plants which are produced and partly to a higher yield per plant. The abnormally low yields reported in Trial 7 were due to a late spring frost which destroyed the first bloom and greatly reduced the total yield.

Applications similar to those reported in Table 20 were repeated

TABLE 22. *Effect of Spring Potash Applications on Yields (in Pounds).*

	No Potash	100 lb. Potash March (as growth starts)
Trial 1—Per cent below ¾ inch	19.8	18.6
Yield 100 Plants	7.87	8.68
Row Yield	71.64	80.05
Trial 2—Per cent below ¾ inch	11.2	12.8
Row Yield	30.73	36.22
Trial 3—Yield 100 Plants	3.54	3.97
Row Yield	26.30	26.13
Trial 4—Per cent below ¾ inch	11.1	10.2
Row Yield	17.42	19.50
Trial 5—Per cent below ¾ inch	5.8	5.6
Yield 100 Plants	2.33	3.98
Row Yield	25.38	27.44
Trial 6—Per cent below ¾ inch	27.7	25.5
Row Yield	28.18	32.34
Trial 7—Yield 100 Plants	3.78	3.15
Row Yield	17.29	18.31
AVERAGE—		
Per cent below ¾ inches	15.1	14.5
Yield 100 Plants	4.38	4.94
Row Yield	30.99	34.28
Crates per Acre	154.6	171.4

1—1933, Triplicate, Blakemore, 1st crop.
2—1933, Triplicate, McClintock, 1st crop.
3—1933, Triplicate, Aroma, 1st crop, poor soil.
4—1934, Triplicate, McClintock, 2nd crop.
5—1934, (5 replications) Aroma, 2nd crop.
6—1934, (5 replications) Blakemore, 2nd crop.
7—1934, (10 replications, poor soil) Aroma, 2nd crop.

following harvest. These applications were made during renovation. The results of three such trials are reported in Table 21. These tests were conducted on a soil of moderate fertility or better and in no case was the influence of either phosphoric acid or potash significant. Additional evidence is found, however, that applications of nitrate of soda following harvest at the time of renovation may be distinctly valuable.

A large group of commercial growers apply muriate of potash in the spring as growth is starting and are firmly convinced that it is their most profitable fertilizer application. Seven trials planned to test the value of such applications are reported in Table 22. In every case except Trial 3, which was on a very poor soil, distinct increases in yield followed the application of 100 pounds of muriate of potash in the early spring. Results of these trials are more consistent than any which have been reported. Detailed yield records of individual trials show great consistency, and there is no doubt but that under the soil conditions of these trials such spring applications of potash were very effective. The average of these seven trials showed an increase of 12.7 per cent in the yield per plant when spring applications of potash were made.

It is difficult to draw definite conclusions from the fertilization trials. Inconsistency is evident in many of these trials, as was found in the records of commercial growers and observations over the state. Certain conclusions, however, appear to be justified. The application of fertilizers is of doubtful value on good land during the first growing year. The only application which has produced uniformly favorable results during the spring before the first crop, was one of muriate of potash as the plants are beginning growth. On poor soils the application of phosphoric acid and potash during soil preparation before planting, and, under extreme conditions, the application of nitrate of soda during the first growing season may be profitable. There is no evidence that application of nitrate of soda in the spring before harvest is likely to prove profitable on strawberries. After the first harvest applications of phosphoric acid and potash will be profitable only on soils below the average in fertility, but applications of nitrate of soda at renovation will probably stimulate the formation of a larger number of runners and increase yields.

EFFECT OF MULCH APPLICATIONS

Evidence from Field Records

The application of a mulch to strawberry fields has long been recommended. Among the 69 records included in this study 24 report an application of mulch. The average cost of the material applied by these growers was $7.79 per acre, and the labor of applying the mulch amounted to $1.85. In most cases this represented a cash outlay and was an item of considerable importance in relation to other cash expenses. In the analysis of production costs it was found that nearly 30 per cent of the growers' cash expense was represented by mulch, and that this expenditure represented approximately 10 per cent of the total cost of production. Fewer growers used mulch material preceding the second harvest and they used less material than was applied following the first growing season.

SELECTION OF PLANTS FOR SETTING

The importance of obtaining a good matted row as early in the summer as possible is generally recognized by commercial growers and the selection of suitable plants for setting is considered by many to be one of the principal factors influencing the results.

Source of Plants

Many people believe that plants imported from a distance have a distinct advantage over locally grown plants and that it is desirable to renew the stock frequently. It is obvious that the presence of serious strawberry pests such as the crown borer, root rot, may make the use of local plants very unwise. Aside from that, the value of importing plants seems doubtful and tests were conducted to provide direct comparisons. In these tests plants were procured from reliable sources in Arkansas, Maryland, and Indiana, and for comparison plants were procured from several successful local growers. The results of these three tests did not indicate a distinct advantage for any one source and indicated clearly that local plants were as desirable, if not more desirable, than those procured from other states. In 1934 the same trial was repeated in order to obtain additional records. This trial was placed on a very good soil and was given careful culture throughout the season. All four trials are summarized in Table 23 together with some detailed records from Trial 4.

It is significant that in every trial the lowest producing plots were developed from imported plants and that in three of the four trials the highest yielding plots resulted from local plants. It is clear that no single source of plants consistently proved superior to others. Variations in yield are explained very much more accurately by the notes which were made concerning the condition of plants at the time of setting than by the source from which the plants came. For example, in Trial 1 the local plants were set as soon as they were received without being heeled-in. Plants from all other sources were heeled-in when they were received and were given uniform care. During the time the plants were heeled-in they started to grow slightly. Those from Mary-

TABLE 23. *Influence of Source of Plants on Yields.*

Source of Plants	Trial 1	Trial 2	Trial 3	Trial 4				Average	
	Row Yields	Row Yields	Row Yields	No. Plants	Row Yields	Per cent Culls	Yield 100 Plants	Row Yield	Crates Per Acre
	Pounds	Pounds	Pounds		Pounds		Pounds	Pounds	
Arkansas	16.25	16.53	29.79	658	46.24	7.0	7.02	27.20	136.0
Maryland	12.53	17.41	19.01	497	26.48	8.4	5.33	18.86	94.3
Indiana	13.54	15.05	22.63	684	42.25	6.1	6.17	23.37	116.8
Local Sources	17.79	18.81	34.92	668	45.85	6.4	6.86	29.34	146.7
	18.24	23.68	32.16	653	41.34	6.2	6.33	28.85	144.1
	16.76	18.78	26.80	598	43.65	5.6	7.30	26.49	132.1

Trials 1, 2, and 3 were harvested in 1931, Trial 4 in 1933.

land and Indiana especially showed definite root action and had formed one or two new leaves. The yields indicate that it is an advantage to set the plants as soon as possible and that when plants have been heeled-in long enough to begin growth they are less desirable.

In a test conducted during the season of 1932 all plants were handled in the same way and all were reasonably uniform except those shipped from a distant state, which had dried slightly during shipment. By careful handling, however, no replanting was necessary in any of the plots. Notes which were made late in the growing season indicate very uniform rows throughout the entire test. The result of this test indicates the importance of good plants and suggests that it is a definite advantage to procure such plants locally and to set them without delay. There is no indication that the importation of plants from outside the state is an advantage if locally-grown plants are available that are free from insects and diseases.

Age and Size of Plants

Practically all nurserymen and commercial growers who supply plants grade out the old crowns and the very small late runners but do include plants varying greatly in size. In order to obtain evidence as to the advantage of large and small plants, trials were planned with this in mind. For Trials 1, 2, and 4, reported in Table 24, a large commercial shipment was inspected and a group of plants representing the largest of the shipment, and another group representing the smallest of the shipment was selected. For Trial 3 a one-year-old matted row which had never fruited was dug. The old plants and the very small ones were discarded, and then from the remainder two groups were selected representing the large and the small sizes. All trials were conducted in triplicate and the results were fairly uniform. The yields were definitely in favor of the larger plants. The number of plants was counted, at the beginning of harvest for Trials 3 and 4, and the greater vigor of large crowns is indicated by the greater number of runner plants that had been formed.

Notes on significant differences were made during the growing season. In each case they indicate that the large crowns started more quickly and required less replanting. Following the planting of Trial 3 a series of rather severe freezes heaved the small plants and made

Table 24. *Influence of Size of Crown at Setting on Runner Plant Formation and Subsequent Yields.*

Size of Crown	Trial 1	Trial 2	Trial 3			Trial 4			Average			
	Row Yield	Row Yield	No. Plants	Row Yield	Yield 100 Plants	No. Plants	Row Yield	Yield 100 Plants	No. Plants	Row Yield	Yield 100 Plants	Crates Per Acre
	Lbs.	Lbs.		Lbs.	Lbs.		Lbs.	Lbs.		Lbs.	Lbs.	
Large.....	15.11	12.44	450	18.07	4.02	1147	58.37	5.09	798	25.99	4.55	130.0
Small.....	9.47	12.10	354	12.87	3.64	966	55.86	5.78	660	22.58	4.71	112.9

1. Set 1930, harvest 1931—Aroma.
2. Set 1930, harvest 1931—Aroma.
3. Set 1932, harvest 1933—Aroma, poor soil.
4. Set 1932, harvest 1933—Aroma, good soil.

replanting necessary. An unusually dry period followed the setting of Trial 4, causing the small plants to suffer much more severely than did the larger ones. It seems clear that the principal advantage resulting from the use of large plants at setting is their greater ability to stand unfavorable conditions, to start growth more promptly and to produce a larger number of runners. Where soil conditions and weather conditions are very favorable small plants will be entirely satisfactory.

Varieties

The problem of selecting the most profitable variety is one which confronts every strawberry grower and which receives more discussion among growers than any one question. There is a tendency to blame low yields and low returns on the variety and to seek the solution for all problems by the selection of a new highly advertised kind.

During the last few years the introduction of many new varieties, among the most important of which are Dorsett and Fairfax, has aroused new interest in this subject. These varieties are being tested by many growers but have not become established in large acreages. During the course of this investigation data have been secured which indicate many important differences among strawberry varieties. For example, in Table 16, Trials 1 and 2 were conducted in the same field and at the same time using different varieties. Premier yielded 40.5 pounds per row under the same conditions that Aroma produced only 17.5 pounds. Unfavorable spring weather was responsible for the comparatively low yield of Aroma. A direct comparison of Aroma and Klondyke can be made in a series of fertilizer tests which were side by side on uniform soil. If all the fertilizer treatments are averaged it will be found that the yield of Klondyke was 27.7 pounds per row while that of Aroma was 23.3 pounds, but the Klondyke produced 16.4 per cent of fruits which were below the minimum size for U. S. No. 1 while the Aroma had only 3 per cent below this size.

During 1931 single rows of Aroma and Blakemore which were growing side by side were carefully picked and the number of berries per pound was determined for each picking during the season. The figures show that throughout the picking season Aroma was slightly larger than Blakemore. This difference became more pronounced as the picking season advanced. Berries of both varieties declined in size rapidly near the close of harvest, but the Aroma was harvested over a longer season and held a desirable size much longer.

In 1931 plantings of Aroma, Klondyke, and Blakemore were made for other trials in this investigation. The conditions in the field were sufficiently uniform to permit varietal comparisons. The plantings were continued for a third crop so that a comparison throughout the life of a commercial plantation was possible. All of these varieties are considered moderate or good plant makers, though Klondyke and Blakemore produced runners more abundantly than did Aroma during the first growing season when conditions were favorable. Both Klondyke and Blakemore produced distinctly larger total yields than did Aroma, but only about one-third so large a percentage of the Aroma fruits were less than three-quarters of an inch during the entire season. It is significant that in a comparatively thick row where there were probably five or six plants per square foot the Blakemore produced large yields per plant.

Throughout the entire life of these plantations Blakemore proved to be most and Aroma least productive. When the yield of fruits above a minimum size of three-quarters of an inch is determined there is much less difference between these varieties. The reports from commercial growers indicate even less difference. Among the production records considered in this investigation, 24 fields of Klondyke produced an average yield of 67.4 crates while 32 Aroma fields produced a yield of 62.1 crates.

In 1935 plantings of Dorsett, Fairfax, Blakemore, and Aroma were made under similar conditions. Weather conditions were relatively favorable during that season and all varieties produced plants freely. At the close of the season the number of plants per row was determined for each variety and it was found that Blakemore had produced the most, 1,840, Aroma was next with 1,300, then Dorsett with 1,124, and Fairfax with 661. Unfortunately a very severe freeze during the blooming season of 1936 made it impossible to obtain representative yields from these plantings. Indications are that the yield from Dorsett would correspond favorably to that of Blakemore and that the Fairfax would be less productive than Aroma.

SEASON OF RUNNER FORMATION

The labor and expense involved in the care of a strawberry plantation is greatly increased after runners begin to set. Most growers believe that it is very important to obtain a good matted row as early in the summer as possible. Nevertheless, many of them have harvested excellent crops following unusually dry seasons during which most of their plants were formed in September. During 1930 some runner plants were staked and dated in order that the importance of early runners could be established. In this preliminary work only a few plants were included, but the yields indicated definitely that there was comparatively little difference between plants which were formed in June, July, or August. Aroma plants formed as late as September 9 produced yields equal to those of plants set in July or August and greater than those of the June-set plants. Following this preliminary work runners were staked during the growing season of 1932 and the yields were obtained from individual plants the following spring. The results indicate that all runners set before early fall have practically equal value. Very early runners frequently are stunted by dry weather during the summer and develop leaf spot or other troubles which reduce their productiveness. During 1932 Aroma continued to set plants much later than did Premier. This variety characteristic is recognized by commercial growers, and very dry weather during July and August is considered more detrimental to fields of Premier than with Aroma.

Additional evidence is presented in Table 25 which shows that the number of runners formed before the middle of July is not a significant factor in determining the yields of the following spring. From the record of a planting of Premier which had had uniform cultivation and fertilization, 15 rows were selected and grouped according to the number of runners formed by July 16. There was no significant difference in the yields produced by rows that had formed the fewest runners by mid-July and the group that had produced most runners by that time. Unfortunately the total number of plants which were present at har-

TABLE 25. *Relation of Early Runner Production to Yield.*

No. Runners 7/16/32	Yield, Lbs. Per Plot	No. Runners 7/16/32	Yield, Lbs. Per Plot	No. Runners 7/16/32	Yield, Lbs. Per Plot
190	82.50	206	102.10	216	95.40
176	93.45	202	78.70	217	70.80
183	94.25	202	86.45	218	106.90
187	131.90	199	86.00	247	115.00
189	95.05	209	120.25	255	95.50
Average	Average	Average	Average	Average	Average
185	99.43	204	94.70	230	96.72

Three rows in each plot, 1/60 acre.

vest was not determined, but it is evident that the yield was not influenced by so-called early-set runners. These results indicate that cultivation may continue without regard to the establishment of a matted row until mid-summer, but that the soil should be kept in a condition which favors the establishment of runners during late July, August, and early September.

It is important, however, that cultural conditions during late summer and fall favor the development of large, strong crowns. In the spring of 1934, before harvest, a matted row of Aroma plants was very carefully examined. Plants in a section of this row were staked and classified in three groups according to the size of the crown. When these groups were harvested it was found that 100 plants with large crowns produced 265 berries weighing a total of 3.38 pounds, and that only 18.3 per cent of these berries were less than three-fourths inch in diameter. One hundred crowns of medium size in this row produced 125 berries weighing a total of 1.8 pounds, while 100 small crowns which had a diameter of approximately one-fourth inch produced only 24 berries weighing 0.35 pound. Competition with grass or weeds, a hard-packed soil, or any condition which does not favor the development of strong crowns during the fall is sure to result in low yields the following spring.

STAND OF PLANTS IN THE MATTED ROW

Strawberry plants become very crowded under the matted-row system of culture so that there is serious competition for moisture and plant nutrients. Tests were begun in 1930 to determine the value of thinning plants at the close of the growing season in order to lessen this competition. The dry growing season of 1930, however, prevented the development of a thick matted row so that when thinning was attempted in the fall it was found that practically none of the plants was closer than 3 or 4 inches apart in the row. Nevertheless, one series of rows was thinned to 6 inches, another was thinned by dragging a section harrow across the row in order to pull out the small late-formed plants which were not well established, and other rows were left as they had grown. The yields obtained in 1931 indicate that there were

TABLE 26. *Effect of Thinning the Matted Row on Yield and Size of Fruit.*

Treatment	Record of Individual Rows											
	Row No.	No. Plants	Total Yield	Per cent Below ¾ Inch	Row No.	No. Plants	Total Yield	Per cent Below ¾ Inch	Row No.	No. Plants	Total Yield	Per cent Below ¾ Inch
			Pounds				Pounds				Pounds	
Thinned with Horse Tool	1	693	42.31	3.22	5	852	46.05	4.99	9	599	36.79	4.46
Thinned to 3 Inches with Hoe	2	749	44.01	4.97	6	660	36.05	5.07	11	526	37.51	4.03
Thinned to 6 Inches with Hoe	3	554	36.39	5.47	7	564	32.41	3.81	10	490	30.58	3.43
Not Thinned	4	1010	51.51	7.69	8	653	41.11	5.31	12	584	38.49	3.49

Treatment	Average				
	No. Plants	Total Yield	Per cent Below ¾ Inch	Yield Per 100 Plants	Crates Per Acre
		Pounds		Pounds	
Thinned with Horse Tool	713	41.72	4.22	5.83	208.6
Thinned to 3 Inches with Hoe	645	39.19	4.69	6.07	195.9
Thinned to 6 Inches with Hoe	536	33.13	4.24	6.18	165.6
Not Thinned	749	43.70	5.49	5.83	218.5

Aroma variety, first crop, set 1932.

no superfluous plants present in any of the rows. The yields were reduced by thinning and were reduced in proportion to its severity. This trial was repeated in 1932 under more favorable conditions. The same plan was followed and hand-thinning was done carefully in order to obtain a uniform distribution of plants. The results of this trial are presented in Table 26. They indicate that crowded plants do compete with each other so that the yield per plant is reduced and to some extent the number of small berries is increased. Nevertheless, in every case the largest total yields were obtained where there were the most plants.

During the harvest of 1933, 12 rows of Aroma plants were selected which had received the same cultural treatment during the preceding season. The plants were counted during the blooming season and the rows are arranged in Table 27 according to the stand of plants. It is significant that the yield per row corresponds closely to the number of plants in the row, though there is a distinct tendency for the yield per 100 plants to increase as the number of plants per row decreases. The number of plants per square foot in those rows varied from approximately six to two—in other words, each plant in the thick rows had about 24 square inches of ground while those in the row with 254 plants had nearly three times that much area. It is clear that rows were not obtained in this test which were sufficiently thick to cause an actual reduction in total yield.

During the harvest season of 1935 short sections of Aroma rows were selected and yield records carefully taken. In one section of row 10 feet long there were 111 plants, representing approximately 3½ plants per square foot. The yield from this section was 7.27 pounds per 100 plants. A second section having 168 plants or about 5½ plants per square foot, produced a total yield of 4.10 pounds per 100 plants. A third section with 275 plants, representing between 9 and 9½ plants per square foot, produced 1.94 pounds per 100 plants. Under the conditions of soil and weather in 1935 the total yield was decreased by crowding when as many as nine plants per square foot were present. The yield per 100 plants declined steadily as the stand of plants increased. These results suggest that under favorable conditions maximum yields will be produced when there are from five to six Aroma plants per square foot of row. The proper spacing no doubt will vary

TABLE 27. *Effect of Stand of Plants on Yield.*

Row No.	No. Plants	Row Yield	Yield 100 Plants	Row No.	No. Plants	Row Yield	Yield 100 Plants
		Pounds	Pounds			Pounds	Pounds
26	754	50.02	6.63	6	422	33.23	7.81
14	647	44.53	6.88	10	401	20.10	5.01
20	616	45.76	7.42	7	364	39.36	8.06
2	584	35.34	6.05	12	325	27.21	8.37
17	542	35.39	6.52	11	261	18.72	7.17
5	525	39.21	7.46	9	254	20.42	8.04
AVERAGE	611.3	42.54	6.83	AVERAGE	337.8	24.84	7.42

Aroma, good soil—set 1932, first harvest 1933.

according to soil conditions, weather conditions, and different varieties. These yield records coupled with many observations lead to the belief that in general there is much greater danger of growing too few than too many plants in the row. Growers who have particularly favorable conditions will naturally space plants further apart at setting, and under unusual conditions may profitably thin the matted row at the close of the growing season.

RELATION OF CLIMATE TO YIELDS

Precipitation During the Growing Season

Precipitation, especially the distribution of rainfall, is by far the most important climatic factor affecting strawberry yields. Some years the rainfall is distributed with reasonable uniformity but frequently there are periods of drouth which cause serious damage to strawberry fields and are responsible for greatly reduced production. In practically all cases the planting season can be adjusted according to weather conditions so that favorable soil moisture, which is so important for the vigorous start of strawberry plants, can be obtained. The renovation of a strawberry field after harvest is much more frequently delayed or entirely prevented by unfavorable weather conditions. Strawberry growers are inclined to give up renovation, however, when with proper methods the fields could be renewed profitably. The previous discussion concerning the importance of renovation soon after harvest emphasizes the necessity of taking advantage of the first rain after the close of the picking season. Favorable soil conditions greatly reduce the labor necessary for the proper renovation of a strawberry planting. This was illustrated during the season of 1933 when a group of experimental plots were thoroughly renovated while the soil was rather dry. This work required 32 man-hours per acre. In 1934 conditions were very much more favorable and this same group of strawberry plots were renovated with 24 man-hours of labor per acre. This represents a labor reduction of 37.5 per cent and may explain, in part, why renovation of the field for the second crop pays much better some seasons than others.

Sufficient evidence has been given in the previous discussion to show clearly the importance of a uniformly good stand of plants and the value of proper cultural practices in obtaining such a stand. Even the best cultural practices cannot overcome the handicap, however, of abnormal weather conditions. Excessive rain may increase the growth of weeds and grass so that the expense of caring for a strawberry plantation is very greatly increased. The opposite extreme, too little moisture, is equally serious. The inevitable result of a severe drouth is a poor stand of plants and a greatly reduced yield.

Rainfall During Harvest

Rainfall during the picking season even more directly affects the production. Excessive rainfall during harvest always causes serious losses. Such conditions cause soft berries which do not stand shipment, and result in large field losses so that the harvest records do not represent actual production.

Seasons of extreme drouth during harvest are responsible for equally severe losses. The amount of loss which results from such abnormal weather conditions is difficult to measure. Notes were made during

this investigation in many fields where production cost records were being kept. These notes show estimated losses ranging from 10 or 15 per cent to as much as 50 or 60 per cent owing to the drouths of 1931 and 1932. Such notes as the following are common and indicate the severity of the damage.

> "The dry season has ruined the size. There is a very heavy set of fruit but not more than one-third was picked."

Another quotation:

> "Fruit very small. About 35 per cent of the berries failed to mature normally,"

and again:

> "Extremely dry. Did not attempt to pick culls. Left probably 50 per cent in the field."

Spring Frosts or Freezes

Spring frosts are the cause of serious damage under some conditions, but the strawberry has a long blooming season and it is unusual for the crop to be entirely destroyed in this way. Some varieties, such as the Klondyke and to a less extent the Blakemore, produce blooms on tall fruit stalks which are held high among the leaves or above them so that frost injury is frequent. Other varieties, such as the Aroma, have very short fruit stalks so that most of the flowers are protected by the foliage and there is less injury from ordinary spring frosts. In 1936 there was a killing frost at one place where records were obtained, about eight or ten days later than the average last killing frost, and at that time early blooming varieties were nearly in full bloom. Counts were made shortly after this frost and it was found that 72 per cent of the blooms which were open on Blakemore were injured and 84 per cent of those which were open on Dorsett were injured, while only 50 per cent of the Aroma blooms showed frost damage. In addition to the different percentages of blooms which were killed it is important to note that there were less than half as many blooms open on the Aroma as on either the Dorsett or Fairfax.

Counts were made during the blooming season, 1937, to get additional information on relative blooming dates. It was found that at the time Aroma had only a very few blooms open, fewer than 100 flowers on a 60-foot row, Dorsett was blooming freely with an average of approximately 1,200 blooms per row and Blakemore was blooming even more abundantly with approximately 1,600 blooms per row. The loss which results from spring frost is not entirely due to reduced yields. A part is due to the production of many imperfectly formed berries which growers call buttons. These berries must be graded out at harvest or the grade of the entire crop will be reduced.

FIELD LOSSES AT HARVEST

During the course of this investigation it has become clear that losses which occur in the field during harvest sometimes greatly reduce the amount of fruit on which the grower obtains a return.

Selling Price

During the seasons 1932-1935, inclusive, the selling price in some sections was so low that profits were very doubtful. Under such conditions a large percentage of the fruit was left in the field. The

seriousness of this situation is clearly shown by the records of 15 Aroma fields for the 1933 crop. Seven of these 15 growers report very little loss of fruit in the field. Four growers report that from 10 to 20 crates per acre were given away, and three of the 15 growers estimated that 25, 30, and 50 per cent, respectively, of the fruit was left in the field when picking was stopped because of unsatisfactory prices.

Carelessness in Picking and Handling

Careless picking and insufficient supervision of pickers is frequently a cause of field losses. In 1934 and again in 1935 observations were made in a field of Aroma where lack of proper field management, careless picking, and similar causes, resulted in the loss of fully one-third of an excellent crop. Often a large percentage of the strawberry crop is picked by the owner's family with the help of the neighbors and very little real supervision is given to the pickers. Under such conditions the work is done very well because all who are engaged in it are interested in the crop. Large growers, on the other hand, employ many pickers who have no interest in the crop and who are inclined toward careless work unless careful supervision is given. Ripe berries may be left in the field and they may be brought in as overripes at the following picking. Green or imperfectly formed berries may be picked in large numbers and fruits which are on the vine may be damaged by crawling or walking carelessly along the rows. Such losses can largely be avoided by proper supervision. Many growers have found that a field boss should be employed to supervise about 15 pickers, and that a careful check of individual work should be made in order to eliminate those who are careless.

Even in a normal year, there are usually two or three periods during which rain occurs on two or more consecutive days. In very wet years these periods may extend to four or five days so that it is almost impossible to get the berries picked before they become overripe. Such unfavorable weather conditions make it necessary to provide sufficient labor to harvest the entire acreage in a minimum of time. It is desirable to harvest every day during the main picking season when weather conditions favor rapid ripening. Commercial growers who are shipping to distant markets often follow the plan of picking only every other day, and frequently allow two days to pass between pickings. With this schedule it was found in 1932 that 61 per cent of the culls at a mid-season picking were due to overripes. A similar determination was made at the next picking and it was found again that 56.3 per cent of the culls were due to the same cause.

Delay in handling the fruit from the time it is picked until it is placed in refrigeration or on the market, and especially exposure of the fruit to the sun, are important causes of loss in many strawberry fields. Careless handling by graders and packers frequently reduces the quality of the fruit as it appears on the market and therefore reduces the returns. If pickers can be supervised carefully and taught to grade in the field so that it is unnecessary to turn the cups in the packing shed much of this loss can be avoided.

Size of Berries

Small size is one of the most important causes of culls. This is true especially during the last of the season. During this study records of

size were made for three crops during the life of a plantation. The proportion of small berries for the last three pickings during the entire life of the plantation averaged with Klondyke 50.6 per cent, with Aroma 11.3 per cent, and with Blakemore 47.2 per cent. Considering the proportions of berries which were below the minimum size during the entire picking season, Aroma averaged 4.3 per cent for the entire life of the plantation, while Klondyke and Blakemore averaged approximately 19 per cent. These large losses due to size may reflect unfavorable weather conditions or careless cultural methods, and are of great importance to strawberry growers.

Classification of Culls According to the Cause

During 1932 all of the culls which were produced on a series of plots were carefully examined to determine the relative importance of different causes. A summary of this information for the season is presented in Table 28. The 1932 picking season was extremely dry and, therefore, the percentage of berries culled because of size was very high. During the blooming season in 1932 there was a killing frost which caused the formation of an unusually large number of "buttons." The most important single cause of culls during that picking season was this late spring frost. The culls which are listed as due to mechanical injury were largely the result of bird pecks. Most commercial growers simply do not pick such fruit and have no measure of the amount which occurs in the field. The low total yields reported are due principally to the reduced stand of plants following an abnormal summer drouth

Table 28. *Classification of Culls as to Causes. 1932 Picking Season.*

Variety	Total Yield Per Row	Weight of Culls	Per cent of Total Yield	Per cent of Total Culls which were:				
				Per cent Below ¾ Inch	Rots	Buttons	Misc. Injury	Over-Ripe
	Pounds	Pounds						
Aroma	6.10	1.02	16.6	14.8	14.2	39.1	19.6	13.6
Blakemore	9.74	1.66	17.2	24.6	10.7	59.3	19.3	13.0
Klondyke	9.64	1.87	19.4	29.3	9.5	62.8	23.2	12.7

during the growing season of 1931. In this examination berries which showed more than one defect were listed in both groups so that the total percentages exceed 100 in most cases. A considerable percentage of those berries which are listed as "buttons" were also less than three-fourths inch in diameter but showed definite evidence of frost damage. The comparison of varieties which can be made in this table is significant. A larger percentage of culls are due to size with Klondyke than with Aroma and a smaller percentage are due to rots. The Klondyke fruit stalk holds the fruit up off the ground so that field rots are comparatively unimportant. The fact that Aroma shows a distinctly smaller percentage of buttons than Blakemore and Klondyke may be due to a later blooming season and to the protection of Aroma flowers by the foliage.

FACTORS WHICH AFFECT THE SELLING PRICE

The profits which are realized from strawberries depend not only upon the cost of production and yields but also upon the selling price. In some respects this factor is less under the control of the individual grower than are those factors which determine the cost of production or the yields per acre.

COMPETITION AMONG WIDELY SEPARATED PRODUCING AREAS

During the early years of the strawberry industry, production was limited to areas closely adjacent to centers of population. Since the perfection of the refrigerator car the producing areas have spread widely and they have become competitors in all of the important markets. More recently the development of an extensive system of improved highways, together with the very rapid expansion of commercial trucking facilities, has further complicated this problem. Truck movements are less accurately reported and market information is, therefore, less reliable than it was a few years ago when practically all perishable products moved into the larger markets over the railroads. These improved means of transportation have brought widely separated areas into direct competition.

It is customary to divide strawberry-producing states into four groups according to their shipping season. The marketing seasons for states in different groups, however, frequently overlap sufficiently to be an important factor in the market supply. Strawberries from the eastern states move into northeastern consuming centers almost entirely and do not occupy any important place in the consuming centers of the Middle West. Comparatively, a small proportion of California strawberries move into the important markets of the Middle West under normal conditons.

TABLE 29. *Classification of Strawberry Producing States According to Season of Marketing.*

Early Group	Second Early Group	Intermediate Group	Late Group
Alabama	Arkansas	California	Indiana
Florida	Southern California	Delaware	Iowa
Louisiana	Georgia	Illinois	Michigan
Mississippi	North Carolina	Kansas	New York
Texas	South Carolina	Kentucky	Ohio
	Tennessee	Maryland	Oregon
	Virginia	Missouri	Pennsylvania
		New Jersey	Utah
		Oklahoma	Washington
			Wisconsin

TABLE 30. *Price Trends from 1930 to 1934.*

Year	Klondyke			Aroma		
	Lowest	Highest	Average	Lowest	Highest	Average
1930	$2.24	$3.00	$2.68	$2.33	$4.01	$3.23
1931	1.93	3.50	2.62	2.26	3.04	2.66
1932	1.23	2.57	1.63	1.66	2.51	1.97
1933	.90	1.15	.98	1.09	1.45	1.28
1934	Not sufficient records			1.10	1.66	1.29

Prices per crate based on the average of the records from commercial growers cooperating in this investigation.

PRICE TREND DURING A PERIOD OF YEARS

The fluctuation in strawberry acreage corresponds closely to the general profitableness of the crop. Acreage changes are less abrupt than fluctuations in selling price and usually lag one or two years behind.

The fluctuation in strawberry prices shown in Table 30 cannot be explained entirely on a basis of the quality and condition of the fruit or the volume which moved into the consuming centers during the shipping season. A more fundamental factor influenced these seasonal trends. In Table 31 information is presented which shows a striking correlation between the price of strawberries, received by the grower and general economic conditions throughout the country. In order to obtain a picture of the general economic conditions, index numbers representing the general business activity, employment, commercial pay rolls, and non-agricultural income were obtained from tabulations in the Annalist of the New York Times and publications by the United States Department of Agriculture. From a comparatively satisfactory condition in 1929 there was a continuous decline in general economic conditions to 1933 which was the low point by all three methods of measuring the conditions. The season of 1933 was also the low point in

TABLE 31. *Figures Showing Strawberry Prices and Indices for Economic Conditions.*

Year	Strawberry Price Per Crate (1)	Business Activity (2)	Index of Employment (2)	Index of Pay rolls (3)	Non-Agricultural Income (4)
1928	$1.90	105.3	97.4	100.4	.....
1929	2.40	114.8	105.1	110.9	107
1930	3.10	101.6	95.2	95.0	100
1931	2.50	89.8	79.9	72.5	85
1932	1.25	66.2	64.7	47.6	67
1933	1.05	74.1	62.1	41.9	63
1934	1.10	85.2	81.0	65.5	70
1935	1.65	82.7	81.8	68.4	75
1936	2.15	94.3	84.8	76.1	85

(1) Average prices received by growers for the crop marketing season. U.S.D.A. Bureau of Agr. Econ., Crop Reporting Board, Strawberries—TC—36: 1233.
(2) *The Annalist.* Published by the New York Times Co. Vol. 47, p. 943, June 1936, and Vol. 49, p. 599, April 1937. The average of the indexes for March, April, May, and June is recorded.
(3) *The Annalist.* Vol. 45, p. 162, Jan. 18, 1935, Table 7, Recent Economic Changes in United States, and Vol. 47, June 1936. (Average 1923—25 = 100)
(4) The Demand and Price Situation, March 1937, U.S.D.A. Bureau of Agr. Econ., Washington, D. C. (Average 1924—29 = 100)

the seasonal strawberry prices. The improvement since that time indicates that the ability of people to buy is a dominant factor in determining the selling price of strawberries.

A study of the individual records in this investigation shows that the fluctuation in the price during the picking season is likewise a factor of importance. The average price of the first picking is, in almost all cases, the highest. The decline in price corresponds roughly with the increase in volume and the progress of the shipping season. During mid-season the largest pickings averaged only 75 per cent as high in selling price as did the first picking. The price at the close of the season after the size and quality of the crop had declined was only 50 per cent as high as it was at the start.

There is a continuous and frequently an extreme fluctuation in price from day to day and, also, a wide variation in the quotations on any given day. Many factors contribute to these fluctuations. The importance of at least three such factors may be seen by a study of the daily market reports. The influence which the variety of fruit has upon the price is very evident. Thus Klondyke and Blakemore consistently sell at a lower price than Premier and Aroma.

The volume of the fruit which is available in the market on a given day can be seen to have a distinct influence on the price, though this effect is often less clear-cut than might be expected. The quality or grade of the fruit appears to be by far the most significant factor in determining its selling price on any given day.

DISCUSSION

Strawberry profits are not determined by the same factors under all conditions. No single one is always of first importance but profits depend upon a favorable balance of many factors. As this study has progressed four things have come to stand out clearly.

First and most important, profits depend on obtaining relatively large yields per acre at a low cost per crate.

Second, though greatly influenced by climatic conditions, (more especially the amount and distribution of rainfall) yield nevertheless depends in large measure on the kind of soil, its preparation, and its proper management after planting. Apparently the preparation and later management are as important as the kind of soil. If the plant bed is so prepared before setting that a good stand of plants is promptly obtained and then so handled that heavy, matted rows are formed, large yields of good grade berries may be expected. In this connection good physical condition apparently plays a more important part than high natural fertility, the use of fertilizers, or mulching materials. On the other hand, soils that are poor or poorly prepared are certain to result in a poor stand of plants. This means that fundamentally the problems of production center around the establishing of the plantation and its care during the first season, even during the first few weeks of that growing season. The old adage, "Well begun is half done," applies literally in the strawberry enterprise.

Third, the most effective way to keep production costs low is through the preparation of the plant bed and the early care during the first season. This early care will increase yields and will help to avoid more expensive care during the later season.

Fourth, though income and profits depend, in large measure, on the selling price and they in turn depend in large measure on the market supply and demand, size and grade of berries are important in establishing price. Both size and grade are largely under the grower's control, partly through the same factors that determine yields and partly through care in harvesting operations.

SUMMARY

The strawberry is an important cash crop on many farms. It is a "family crop" because it is adapted to small acreages and requires a large amount of hand labor.

The economic depression has prolonged the period of low returns so that the industry has passed through a serious crisis during the last six years. The present investigation extends through that period of low returns. The information reported in this publication is based upon an analysis of production records obtained from commercial growers and upon field tests which were planned to check the importance of many factors, influencing strawberry profits.

Profits depend upon three general factors—namely, the cost of production, the yield per acre, and the selling price.

The records show that the cost of production represents nearly half of the total cost for the first crop; harvesting and handling the fruit after it was mature accounted for approximately three-fourths of the cost for the second crop.

The principal item of overhead or fixed cost was a charge for the use of the land. Depreciation of equipment was a very small item because expensive tools are not required for strawberry growing. Most of the cash expenses were incurred during the establishment of the plantation. The cost of plants and fertilizer were the principal items. Labor represented the largest expense in the production of strawberries. An average of 163.6 man-hours and 63.9 horse-hours per acre were required for the care of the plantation before the first crop. Less than one-third as much labor was required for the care of the plantation between the first and second crops. The establishment of the plantation required 30.2 per cent of the total labor during the first year.

Picking represented 48.2 per cent and the cost of the packages represented 30.6 per cent of the total cost after the fruit was mature. Grading, picking, supervision, and hauling are other items which were included in the total.

Strawberry yields depend upon many factors, no one of which was found to be of first importance under all conditions, though character of the soil is a factor of first importance in most cases. A sandy or gravelly loam in good physical condition, with abundant humus, moderately fertile, and well drained is considered to be the ideal soil for strawberry production. The care which the soil has received during the years preceding the setting of the plantation is of great importance. Thorough tillage during these years leaves the soil in good physical condition and reduces the problem of weed control.

For the production of high yields, cultivation should be thorough, timely, and continuous through the first growing season. Neglect or delay is not economical of labor. The depth of cultivation is com-

paratively unimportant under normal conditions, but it should be adjusted according to the type of soil and the available moisture. Tillage after the first crop will increase yields but it may increase greatly the cost per crate if soil conditions are unfavorable. The method of cultivation following the first crop should be determined according to the conditions in each field.

Fertilization is of doubtful value on good soils. The application of nitrogen is profitable at the time of renovation following harvest, and possibly on poor soils when applied at the time of setting. Spring applications of nitrogen before harvest are often not profitable. Applications of phosphoric acid and potash during the growing season are helpful on soils which are below average fertility. Potash applied in the spring as growth is starting gives the most consistently favorable results.

The selection of suitable plants for setting is a factor of importance. The source of the plants, however, is unimportant so long as they are free from insects and diseases and are in good condition at the time of planting. Plants of large size are not essential but they have a distinct advantage under unfavorable conditions and will usually start growth more vigorously after setting.

The time of runner formation and the development of the matted row is not important before late summer, provided soil conditions are favorable for the development of large crowns during the fall. Thorough cultivation is essential for the development of vigorous crowns under ordinary conditions.

The stand of plants in the matted row is one of the most important factors affecting strawberry yields. Many factors are important principally as they influence the stand of plants. For example, the application of nitrogen at the time of renovation, the method of renovation practiced, the size of plants set, and even the method of cultivation are of importance principally because of the influence they have on the number of plants which are developed. Total production increases with the stand of plants under normally favorable conditions until eight or nine plants per square foot are present. Crowding beyond that point results in reduced total yields. The yield per plant declines as the stand increases and the proportion of large fruits decreases in the same way. Probably the best stand varies with conditions, but under the conditions of these tests five or six plants per square foot produced the most profitable yields. Variety characteristics influence the most desirable spacing of plants in the matted row.

Climate is a very important factor but is largely outside the control of strawberry growers except as a consideration in the selection of a suitable site for the planting. Spring frosts or freezes are often serious (1932 and 1936 during this investigation). Excessive rain during the growing season encourages weeds and increases the expense of thorough tillage. Excessive rain during harvest increases field losses by causing soft berries and preventing regular picking. Drouth is a more common cause of injury. A dry growing season reduces the stand of plants and, if severe, prevents the development of large, vigorous fruiting crowns. Drouth during the harvest season reduces the size of fruits, and, under extreme conditions, prevents many fruits from maturing.

Field losses are important in determining strawberry profits but are very difficult to measure. Unsatisfactory prices which caused a large quantity of fruit to be left in the field was found to be an important item during the period covered by this investigation. Most of the losses which occur in the field, however, may be charged to carelessness in picking and handling the fruit or to the decline in size of fruit as the season advances. Variety characteristics, weather conditions, and poor culture are important causes of this decline in size.

The most important factor affecting the selling price of strawberries is the ability of the consumer to buy. The price trend follows the economic cycle very closely.

The fluctuation in strawberry prices from day to day is influenced by the volume of fruit which moves into the markets, by the varieties offered for sale, and by the quality of the fruit. The most important factor affecting the selling price on any given day is the quality and condition of the fruit.

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