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For any single orchard, over a period of several years, prices for fruit marketed vary more than the cost of production. Considering all lands planted to a single fruit crop, however, cost of production varies more widely than prices. Prices high enough to make all orchards profitable are more or less accidental and decidedly infrequent; prices low enough to make all orchards unprofitable have been, one the whole, rare, in Michigan. Other things equal, production costs per bushel are consistently low where crop yields are consistently high. Assuming equal skill in management for all orchards, those with the best locations will have the highest yields and the lowest costs per production unit. Management above the average may make a location below the average reasonably profitable, but not in degree commensurate with the skill applied; with good locations mediocre management may get good results. Good managers and poor managers alike should seek good locations for their orchard enterprises.

A "good location" is one that fulfills several almost opposing requirements, in all seasons, for 20, 40 or 60 years: (a) It must be free of high water table in wet periods and yet supply moisture during drought periods; (b) it must be high enough above the adjacent country to insure reasonable freedom from spring frosts and the lowest winter temperatures, and still it must not be subject to erosion, if cultivated; (c) it must be able, after years of cultivation, to meet increasing, rather than decreasing, demands for nutrients and for moisture.

These specifications, formidable at first glance, are not impossible or even unreasonable. In Michigan there is enough land which fulfills these requirements to accommodate all the fruit trees now growing here, at proper spacing, and still leave room for expansion. It is extremely unfortunate that much of this good orchard land is not utilized, while thousands of acres of orchards in locations never or no longer good are cultivated under disadvantages that waste untold effort and considerable expense.

This publication is intended for several groups of people. For those who plan to grow fruit, the bulletin should aid in choosing farms. To those who have farms, it should indicate the best fruit-growing site or, perhaps, discourage them from attempting a planting. To those who have orchards the bulletin may point out the processes by which a good location may become poor and whether these processes may be arrested; or it may lead the growers to see clearly the enormous cost of improving a poor location and to face courageously the wisdom of discontinuing that particular enterprise. Local history is not a sufficient guide; many sites that once supported good orchards are now incapable of growing even mediocre trees.

Factors which should be considered in selecting a site for an orchard or small fruit plantation are: (1) soil, (2) topography, (3) local climate, and (4) location with reference to transportation and markets. Wherever any one of the first three factors is unfavorable, the cost of production is always higher with equally efficient management. Wherever the fourth is unfavorable, the price received per bushel is lowered, even with equal salesmanship.

Soil, topography, and local climate are all variable in southern Michigan; only a small percentage of the total area comprises sites where all of the factors are especially favorable for fruit growing. Nevertheless, the aggregate acreage of first class orchard sites is considerable. Many fairly successful plantings are found where the land is not first class in every respect, but certainly considerable caution should be used in attempting to utilize land where only one of the above mentioned elements is especially favorable. Drainage, irrigation, terracing, large fertilizer applications, and orchard heating may be used to overcome natural deficiencies, but because of the increased production cost, orchards where such treatments are necessary are seldom as profitable as those on sites not requiring treatment. Sites considered unsatisfactory because of soil or local climate are almost invariably unsuccessful unless local marketing conditions are exceptionally favorable. If a single factor is decidedly unfavorable, even though the other elements are extremely favorable, utilization of the site for fruit growing will usually prove to be a mistake.

Economic Influences

A detailed discussion of horticultural economics is beyond the scope of this publication, but some considerations should be mentioned since a little thought might cause a prospective grower to alter the nature of the planting or even abandon his plans. Distance from market influences the prices received by the grower since he must pay directly or indirectly the transportation charges; hence, the selection of the best sites is most essential at points distant from markets. Favorable marketing conditions have been partly responsible for the large development of fruit growing in Berrien county and the plantings in the vicinity of Detroit. The probable supply and demand for the produce should be considered. For example, there are sufficient red cherry trees now set to provide for any probable demand in the immediate future. The same may be said of Concord grapevines. Nevertheless, if a skilled grower of these fruits contemplated an additional planting, the unfavorable national marketing conditions might be surmounted—provided the soil, topography, local climate, and local markets were all especially favorable. The prices received for fruits and the cost of their production (labor, machinery and supplies) are variable and do not fluctuate together. Some sites might be suited for production at one time and unsuited at another. These marginal sites, however, are always relatively less valuable than others where conditions are more favorable. Few persons have been very successful in forecasting price trends, but an attempt to consider forecasts may be worth while. Since markets pay more for some varieties than for others, an attempt should be made to determine the demands of the particular market and its trend in preferences before selecting the varieties to be grown. Complete success in an economic analysis of the prospects of any projected planting may be impossible, but a forecast even partially correct is usually better than no forecast at all.

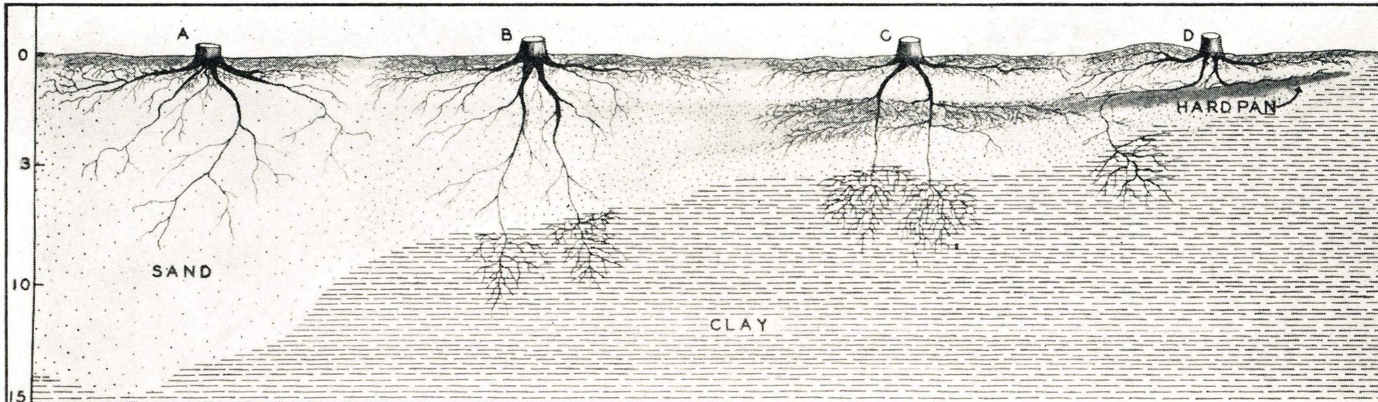
Soils For Fruit Growing

Some idea of the influence of soil structure and texture on root penetration and development and also some knowledge concerning the ability of the various soils to supply required moisture and mineral nutrients is necessary before any particular site may be evaluated. Diagrams illustrating the influence of some common soils on root development are presented in Figs. 1 and 2. The roots range farther and penetrate deeper in deep, open sand (Fig. 2-A) and are more limited in heavier soils (Fig. 2-D). Certain structural conditions, such as hardpan development (Fig. 1-D), prevent deep root penetration. A common condition which prevents the development of deep root systems is water-logging during portions of the growing season, resulting in poorly aerated sub-soils. Such conditions are not restricted entirely to low grounds climatically unsuited for orcharding; they are also found in depressions on uplands and even on hillsides. The diagrams indicate how root development is modified by soil structure and how prolific root growth takes place in those soil layers which are most favorable.

Soils in which trees are shallow-rooted generally produce unsuccessful orchards. This statement, however, does not imply that all soils which permit the development of extensive and deep root systems are necessarily good soils. No matter how far or how deeply the roots may penetrate, the soil will be unfavorable unless the roots reach sources of mineral nutrients and moisture sufficient to meet the requirements of vigorous, mature trees throughout the whole season. For example, in deep, dry sands the roots penetrate deeply and range widely but are unable to find either enough moisture or mineral salts to meet the requirements of vigorous mature trees. The most favorable soils are intermediate in texture, with sufficient sand and gravel in the subsoil to permit internal drainage and the penetration of roots to moderate depths—five to eight feet in the case of apple trees—but with sufficient silt and clay to retain enough moisture for the trees during periods of drought.

Deficiency or excess of a single mineral element or compound, other than a deficiency of nitrates, is rarely a cause of failure in growth or of low fruit production on soils otherwise favorable. Some soils show only very small amounts of lime in the surface layers, but in Michigan nearly all soils contain an abundance of lime at depths within the reach of tree roots. Phosphorus is low in some soils, but apparently there is no extreme deficiency. Soluble aluminum and iron compounds, which might be injurious, have been found in only a very few instances, and then usually in soils otherwise unsuited for fruit growing. In a few soils some water-soluble manganese has been found, but this element apparently was not injurious, since tree growth was good.

Although the range in acidity in the surface layers was found to be moderately wide, no definite correlation with either good or unsatis-



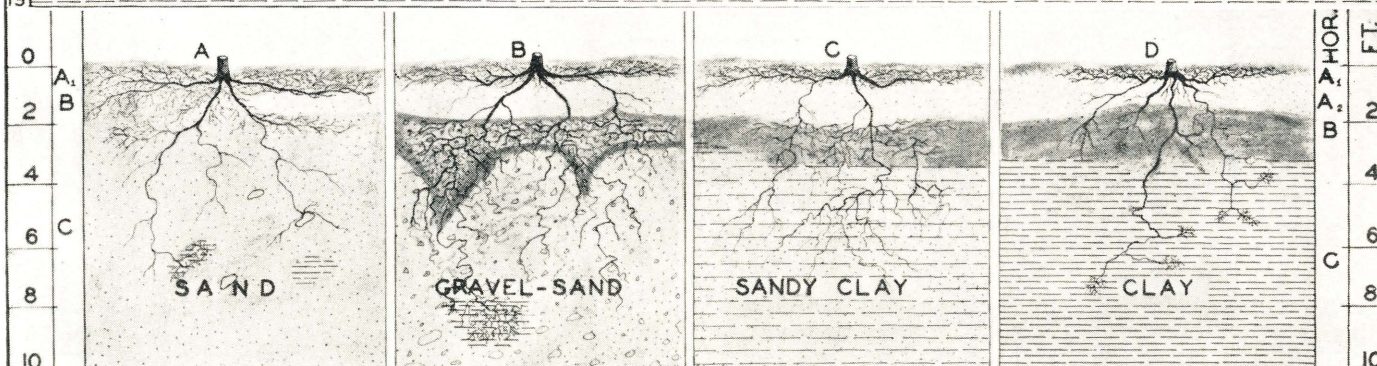


Fig. 1. (Upper) Sketch showing root development in relation to soils, given a variable thickness of sand over impervious clay. This condition prevails on the broad plains bordering Lake Michigan.

Fig. 2. (Lower) Sketch showing root development in relation to representative soil profiles, and to the textural composition and structure of the underlying glacial deposits.

factory growth was established within the limits found in numerous tests. Excess of lime, spots of "alkali," or excess of nitrates were not found to any considerable extent. *Water—the amount in the soil and its availability throughout the growing season— is of greater importance than any other single factor.*

Classification of Soils—The major groups of mineral soils based on textural and moisture relations, which are significant in plant growth, are: (1) the dry, sand-gravel group; (2) the well-drained clay soils; (3) the wet or water-logged sand-gravel; and (4) the wet clay group. Each of these major groups may be subdivided into a great number of types, sub-types and phases, depending on the refinement in recognizing differences in the texture, structure and chemical composition of the

Fig. 3. An illustration of the gravelly nature of the substratum and the variable thickness of the reddish gravelly clay subsoil (indicated by 2 and the darker shade) characteristic of the more gravelly soils on the Fox and Bellefontaine soil types.

separate natural layers constituting the soil profile. As has been shown by diagrams (Figs. 1 and 2), the profile is especially significant in the study of the growth of fruits, since soils vary, with depth, in the amount of moisture, the amount of available chemical nutrients, the acidity or alkalinity, and penetrability.

It is important to recognize at least three conditions in the first major group, the dry sands: (1) soil having a subsoil or horizon between the surface layers and the dry substratum sufficiently clayey and of sufficient thickness to hold moisture and to retard the rapid downward movement of water (Fig. 3); (2) a clayey substratum or silty layers within five or six feet of the surface (Fig. 4); (3) loose pervious sand to depths of six feet or more without any clay intervening. The depth at which a clay substratum becomes significant depends on the plant grown and the extent of root penetration. The first two conditions are more favorable for fruit growing than the third, since such soils are able to supply larger quantities of moisture during dry periods and since soluble salts are not leached from those soils as rapidly as from the deeper sands.

In the second major group (the well-drained clay soils) important differences lie in the texture and compactness or penetrability of the underlying clay. Three types may be recognized, ranging from the most compact and difficultly penetrable clay (Napanee and Kent soil types) through an intermediate texture and structure (Miami and Isabella) to more sandy, friable and penetrable clay (Hillsdale and Montcalm).* The soils of the two latter groups, other conditions being favorable, are more valuable for fruit growing since their more friable structure permits more extensive root development. A photo-

Fig. 4. The photograph illustrates sandy clay and thin wavy layers of silt and clay which in places underlie the deep yellow sand soil of the Coloma sand soil type.

graph (Fig. 5) of the profile of a Miami type of soil shows shrinkage cracks in a compact, gritty, clay subsoil, in which roots have been able to penetrate to depths of four to five feet or more.

In the third group (the wet, sandy soils), the thickness of the sand above the clay substratum and the presence or absence of sandy hardpans constitute the most important bases of differentiation. The acid soil, consisting of a thin covering of sand over plastic impervious clay, is designated as the Allendale soil type; thicker and wetter sand underlaid by sandy hardpan as the Saugatuck type; deep water-logged sands or sandy loams without any hardpan, the Newton and Granby types. Sandy and gravelly soils, which have sandy and gravelly clay above

*The soil type names are included for reference in counties where soil type maps of the Bureau of Chemistry and Soils of the U. S. Department of Agriculture are available.

water-logged sand and gravel, include the Gilford and Brady types; and sandy soils not notably wet at the surface but becoming mottled and permanently moist at three to four feet, the Berrien type. Excessive water, lack of aeration, and possibly toxic chemical compounds in the water-logged, gray or rusty yellow-mottled subsurface horizons are unfavorable factors since they cause shallow rooting or otherwise

Fig. 5. A profile of a soil underlaid by a compact hard clay. Cracks in the clay permit the penetration of the roots to depths of five feet or more.

greatly shorten the life of the trees. Vigorous, mature apple orchards are seldom, if ever, found on any of the soils of this group. Fruits with a smaller total acre demand for water, however, such as peaches and cherries, survive on the relatively deep sands of the Berrien type. Raspberries and strawberries may succeed on the more poorly-drained sands, such as the Newton and Granby types, since their root systems naturally do not penetrate as deeply as those of the tree fruits. The

Saugatuck and Allendale types are generally unfavorable for all fruits except possibly blueberries, and in general the soils of this group are never as favorable for orcharding as the better ones of the second group, the well-drained clay soils.

In the wet clay group, the indicators of adaptation and possible uses of the land are: (1) the texture of the underlying clay, such as fine plastic clay, free from sand, gravel or bowlders, on the one hand, and more penetrable and less impervious sandy or stony clay on the other;

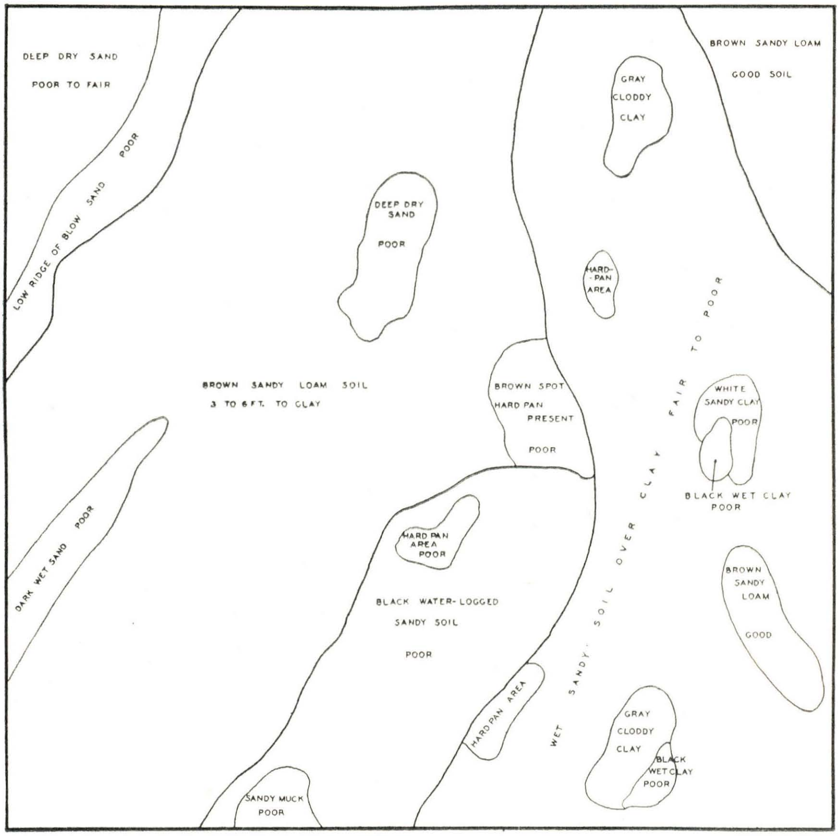


Fig. 6. Sketch illustrating variations in a tract of 40 acres representative of wet sandy soil group.

(2) the color of the surface soil, whether gray, brown or black, indicating differences in moisture and amount of organic matter; and (3) the uniformity and thickness, whether the clay extends to depths of four-five feet, or more. This group of soils is fertile and durable under cultivation but usually occurs in topographic situations unfavorable for fruit growing.

Miscellaneous soils, occurring in small bodies but significant locally in fruit growing, comprise: (1) various kinds deposited in the bottoms of pot-holes and swales and originating from the wash of adjacent slopes; (2) hard clay spots and other exposures of the substrata of various textures, due to erosion; (3) whitish or very light gray soils caused, presumably, by extreme variations in the amount of water in the surface layers of the soil; (4) brown, yellow and red ochreous soils, due to precipitation of iron as an oxide in the vicinity of existing or former seepage springs, and bog iron ore hardpan soils on the borders of marshes or muck swamps. The depositional soils of the first group are more fertile than the surrounding slopes or uplands and may be suited for fruit growing, provided the soils have good subsoil

Fig. 7. Old apple trees (Baldwins) probably about 60 years old. The trunk of the tree in the foreground measures 85 inches in circumference and the tree is healthy and vigorous. It shows the possibilities of apple trees set on those soils which are able to supply large quantities of moisture, permit deep rooting, and at the same time afford an abundant supply of mineral elements.

drainage and are so located that the sites are free from frost danger. The other three groups are all unfavorable for fruit production.

In addition to the mineral soils, a large aggregate of muck and peat soil is widely distributed throughout southern Michigan in both small and large bodies. The topographic situation and local climate are generally unfavorable for fruit growing and the soil itself unsuitable, except possibly for a few crops, such as blueberries or cranberries, on the acid and wetter peats.

Michigan soils are variable in character and should be devoted to crops adapted to their individual peculiarities. When a number of soils exhibiting wide differences occur, however, in a small tract of land, it becomes impossible to lay out orchards or small fruit plantations to conform to the soil variations; hence, these variable areas must be given a low rating for fruit growing. A plot of an area with varied soil is illustrated in Fig. 6.

Moisture Relations—Since the water requirements of plants vary and since there is a wide range in moisture in the soils, it is imperative to select those crops that are best adapted to the available soil moisture. Mature apple orchards require abundant supplies of moisture since the trees reach large size and carry a large leaf surface. The best apple orchards, consequently, are confined to those soil types which

Fig. 8. View of the remains of an apple orchard, about 30 years old, on dry, Plainfield sand. Although young orchards may appear vigorous and thrifty when fertilized, most of the trees die when they become large enough to demand more water than the soil is able to supply. A few scattered trees remain which are able to live because of the large volume of soil reached by their extensive root systems.

have a large supply of available moisture. Either the entire underlying mass of soil reached by the roots of the trees has a large admixture of clay or silt, as in the well-drained clay soils, or the orchard may be on a sandy soil underlaid at depths of five-eight feet by relatively impervious clay, above which moisture moves or in which it accumulates—as in the deepest of the wet, sandy soils or the thinnest of the dry, sand-gravel group. A large number of the most successful apple orchards are found on soils of the class first mentioned, the well drained clays. Figure 7 illustrates an old tree on such soil. When the clay is relatively impervious or impenetrable in the surface layers of the soil, as it is on many portions of the Napanee or Kent soil types, the root systems do not extend so widely nor so deeply, and moisture relations are not as satisfactory as on the more open and penetrable clays. Water in the underlying soil on most of the dry, sand-gravel soils is not sufficient to meet the requirements of vigorous apple orchards. The weak growth of apple trees on a very dry sand is illustrated in Fig. 8. Although apple trees do not die so quickly as stone fruits on soils with somewhat imperfect subsoil drainage, they are not immune to injury on such soils and are usually short-lived.

Pear orchards are similar to apple in water requirements, and the most vigorous growth and largest trees are found on soils similar to

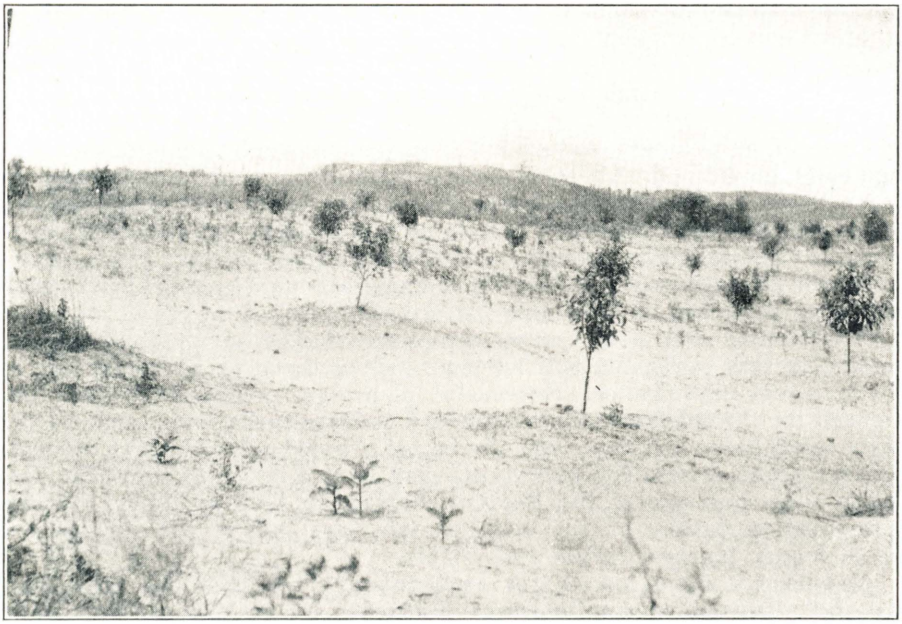


Fig. 9. Young cherry orchard set on deep sand soil which had been denuded by wind erosion and the fertility exhausted before the trees were planted. Failure of the orchard is certain under such conditions.

those best suited for the apple. Pear trees, however, live longer than apple trees on spots somewhat deficient in drainage and tolerate clay soils that are relatively impenetrable, such as the Napanee or Kent silt loams. They will also exist and produce high quality fruit on soils too dry for apple orchards, but the trees do not reach large size, and the acre yields are smaller than in orchards on the moister soils. Tree management, however, seems to be somewhat simpler on the drier soils.

Since peach and cherry orchards do not require as much moisture as do apples and pears, profitable orchards of these fruits are found on soils too dry for apple orchards. Those soils of the dry sand-gravel group which contain admixtures of sil' in the subsoil at depths of three to six feet or a layer of clay at a depth of two or three feet (the first and second classes of this soil group) supply sufficient moisture to produce good crops in most seasons. The third class of this soil group is too dry to support these fruits. A view of an unsuccessful cherry orchard on deep, dry sand is given in Fig. 9. These fruits are even more susceptible to defective drainage than the apple, and the soils of the wet clay or waterlogged sand-gravel groups should usually be avoided, although fairly satisfactory orchards are sometimes found on the Berrien soil type. The gently rolling, uneroded, well-drained, more loamy clay soils are very favorable for the growth of peach and cherry trees. In some instances nitrogen fertilizers may produce excessive growth on such soils and, therefore, should be used with caution. In a few places. successful peach and cherry orchards have been observed on the more compact and impenetrable clays. The natural silty surface soil, however, should be unusually thick or the plow soil deepened since the roots can not penetrate the underlying clay very readily or rapidly.

Grapevines are able to exist on nearly all soils except those very imperfectly drained. There is little foliage on an acre of vineyard in comparison with orchards of tree fruits. The vines root deeply in dry sand soils and apparently are able to obtain considerable moisture, since they are not killed by drouth. Nevertheless, vineyards are more vigorous and productive on soils with a moderate moisture capacity, such as those described as favorable for stone fruits.

Raspberries and strawberries are more shallow-rooted and require moist surface soils; the soil horizons below three or four feet are of little direct significance. Successful plantings, consequently, are observed on the loamier soils of the dry sand-gravel group, such as the Fox sandy loam soil type, and the better drained soils of the wet sand-gravel group, where the underlying clay is at a depth of four-five feet, as in some portions of the Berrien, Newton or Granby types. Berries are most successful on the well-drained clays, where the surface soil is of loamy texture, fertile and friable.

Dewberries have low water requirements; at least the most successful plantings in southwestern Michigan are on dry sands, usually of sufficient depth to be classified as Plainfield, which is as dry as any of the soils of its group.

Fertility Relations—Fruits respond to differences in the fertility of soils as well as to their capacity to supply moisture. Deficiency in fertility limits the productivity of fruits much more frequently than does its excess, at least in Michigan. Instances have been observed, nevertheless, where grapevines were unproductive because of too vigorous, over-vegetative growth and blackheart or even winter-killing of stone fruits occurs on the most fertile spots especially when the trees receive nitrogenous fertilization. In general, the native fertility of Michigan soils varies with the organic matter content. Those soils whose surface layers are sandy, open in texture and dry are usually lower in humus than the loams or clays, fine in texture and permanently moist or water-logged. Since fruit growing is confined largely to uplands, the low-lying wet soils of highest fertility are generally avoided for reasons other than their excessive fertility. Fruits usually do best on soils of moderate fertility, but when the upland soils of Michigan are considered alone, there are few instances where the soils are of excessive fertility. Instances may be found where soils of high fertility occur in depressions and alluvial fills in gently rolling plains, but it is usually difficult to differentiate the losses due to excessive fertility from those due to imperfect drainage.

Over-vegetative grapevines are observed more frequently than over-vegetative fruit trees. These vines are of low productivity but are not especially subject to winter-killing. Vineyards usually do not become over-vegetative except on soils of at least moderate fertility, fertilized with nitrogenous materials. Peaches and cherries growing on soils of moderate fertility are more subject to winter injury or black heart when nitrogenous fertilizers are applied than withheld. Apple trees seem less liable to injury from excessive fertility than other fruits under Michigan conditions. Nevertheless, the maturity of the crop is delayed and the fruit is usually somewhat deficient in color on very fertile soils or when nitrogen fertilizers are used in heavy applications on soils of moderate fertility.

Southern Michigan soils are underlaid by glacial deposits which exhibit wide differences in mineral composition, soil texture, and structure within very short distances both horizontally and vertically. Plantings often have been made because a successful orchard was located close at hand, the assumption being that the soil must be similar and the new orchard as satisfactory as the old one adjacent. Proximity, however, is not always evidence that the soils are the same, even where two sites appear to be the same in topography. The character of the soil should be determined by a careful test of surface and subsoil.

Topographic Features of Orchard Sites

Slopes are of special significance in the evaluation of land for orchard use. The most practical classification of these is on the basis of gradient, expressed in percentage of rise per hundred feet of horizontal distance, and the grouping of gradients into five classes, namely: (1) level to 3 per cent; (2) 3 to 8 per cent; (3) 8 to 15 per cent; (4) 15 to 25 per cent; and (5) slopes greater than 25 per cent. The reason for directing attention to the degree of slope is because, other elements being the same, erosion due to washing varies directly with the steepness. Erosion is probably responsible for larger losses of soil fertility than any other factor in Michigan. Although large differences in the texture and native fertility of soils exist, as has been mentioned in the preceding discussion, all soils exhibit losses of fertility by erosion resulting from clean cultivation on slopes. The greater the degree of slope, the more rapid and destructive the erosion, other factors being the same, and the lower the rating that must be given the site for prospective orchard utilization.

The three topographic components of all rolling, hilly or broken land are: (1) the level tops of ridges or table land, (2) the slopes, and (3) the lake basin, dry pit depression, and bottoms or valley land at the foot of the slopes. The relative proportion of the three components, in conjunction with the amount and distribution of the different classes of gradients, largely determines the topographic rating of a location. The relative growth of peach trees on three topographic phases of a tract of land occupied by a sandy clay soil—(1) level upland, (2) a moderate slope and (3) a depression occupied by deeper, more fertile soils—is illustrated in Figs. 10, 11, and 12. A similar series of trees on a soil of intermediate texture is shown in Figs. 13, 14, and 15. Similar differences are observed in the growth of grapevines on a sandy soil (Fig. 16). Space prevents the illustration of similar series for all our fruits on all rolling or hilly land in Michigan. It is worth repeating: *The greater the erosion, the weaker the growth made by the trees in comparison with plantings on less eroded soils of similar character.*

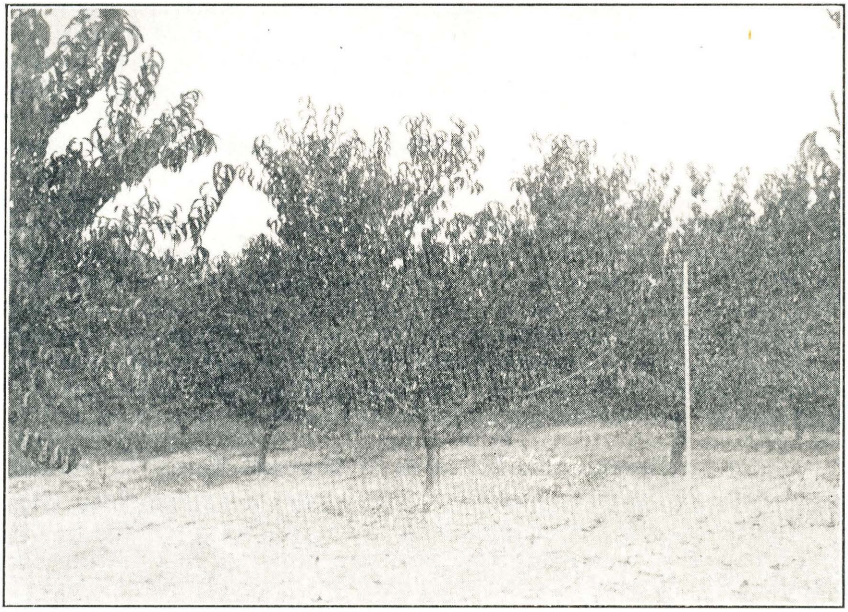


Fig. 10. Peach orchard, five years old, on Miami soil type. A tree set on the comparatively uneroded upland; circumference measurements of representative trees were: 11, 11.5, 11.5, 12.5, 12.5 inches. Compare with Figs. 11 and 12.

Classification of Topography—The more important topographic features which have significance in rating an orchard site topographically are enumerated below. They may be found in areas with various sorts of topography, but the rating depends on the nature of the site itself rather than its surroundings. A level upland in the midst of very broken country, thus, would be given a favorable rating even though the associated slopes were generally unfavorable.

1. *Plains of sufficient size for orchard sites with most of the area occupied by slopes of the first class, not exceeding 3 per cent, although small areas of second degree gradients may be present.* These comprise the sites where erosion due to rainfall runoff is at a minimum. These plains must be given the highest rating on a topographic basis. Blowing or

Fig. 11. (Upper picture) A tree on a slope of about 12 per cent but a point where there was little gully formation. Circumference measurements of representative trees are: 9, 9.5, 9.5, 10, 11 inches. Compare with Fig. 10.

Fig. 12. (Lower picture) Peach orchard on Miami soil type. The trees are growing on the deep fertile soil of a shallow depression. Representative trees are 18, 18, 18.5, and 19.5 inches in circumference. Compare with trees shown in Figs. 10 and 11.

Fig. 13. (Upper picture) Peach trees, set four years, on level uneroded Fox loam. The average circumference of trees is 9.9 inches. Compare with Figs. 14 and 15.

Fig. 14. (Lower picture) Same locality as Fig. 13 and trees of same age on eroded slope, about 10 per cent gradient. Average circumference of trees, 6.7 inches.

wind erosion, however, may be serious where the soil is composed of deep loose sand. Whether any specified plain is suited for orcharding will naturally depend on the character of the soil and its local climate.

2. *Broad ridges with gentle slopes situated on broad plains.* These sites are given a favorable topographic rating since the ridges consist of slopes of the first or second degree, that is, not exceeding 8 per cent. Destructive erosion does not develop as rapidly and is not so difficult to control as on the steeper slopes.

3. *Sites which are rolling, whose slopes are mainly of the second degree, with only a small proportion of third degree slopes ranging up to 15*

Fig. 15. Same locality and trees of same age as in Figs. 13 and 14. Tree is growing in a depression at the base of the slope, where the soil is deep, dark colored, and well-drained. Washtenaw type of soil. Average circumference of trees, 13 inches.

per cent, with some more level areas on the ridge crests and hollows. This topography is intermediate in character and should be given a higher or lower rating within the class, depending on the proportion of slopes to the more level land.

4. *Broken country, characterized by higher hills and with steeper slopes of the third, fourth and fifth classes dominant (the rise above 15 per cent).* This land is generally unfavorable for orcharding. Erosion under cultivation is more rapid and destructive on such slopes, and the percentage of level land on a site in this class is usually very small. Even though it is possible to keep the orchard in sod, the slopes add to the

difficulties of operation. Further, the use of sod is feasible only where the soils supply sufficient moisture to answer the needs of both the trees and the grass. It would appear that the deficiencies of fertility which occur on slopes because of the loss of the more fertile surface layers could be corrected easily by the application of fertilizers. Experiments and the experiences of many growers show that this is difficult and expensive, if not impossible. The rating to be given this sort of topography will be more unfavorable the greater the degree of slope and the smaller the percentage of level land. If such slopes are set, destruction of the land may be avoided by sod or heavy mulching but the possibility of profitable orcharding is small on sandy or gravelly soils.

Fig. 16. Coloma soil type. Grape vineyard with part on the crest of a sandy ridge with moderate growth; part on the steep slope where water erosion and gullying has occurred, and where the vines are very weak or dead; part on the Washtenaw type of soil at the foot of the slope where the growth is vigorous in spite of the recent coarse wash which has nearly covered some of them.

Variable Sites—In many instances a site that is generally favorable from a topographic aspect may be broken by some unfavorable feature, such as a stream valley, a low, abrupt ridge, a bluff or a pot-hole depression. The rating of the site is reduced according to the acreage and location of the unfavorable conditions. The question will arise, if it is decided to utilize the site, as to whether it is better to set the unfavorable land in fruit or leave vacancies in the orchard. If the feature is a small abrupt ridge or pot-hole, it may be better to set it, to simplify orchard operations. Erosion, however, is destructive not alone on slopes where soil removal occurs but may be destructive also at the foot of a slope because of the deposition of quantities of coarse wash (Fig. 17). Further, gullies frequently will form on abrupt slopes and then extend back into the more level upland, destroying the more valuable areas more or less rapidly. Where the possibility of ruining the more favorable portion of the site by cultivation occurs, the unfavorable portions should not be set to fruits demanding cultivation. If set, these slopes should not be cultivated even though the trees be stunted, since the certain injury to adjacent areas will not be met by any possible production of the trees set on the slopes. When the or-

Fig. 17. Oronoko land type. Destructive accumulation of wash at the mouth of a gully in a raspberry patch.

chard is kept in sod, the steep slopes are less subject to severe damage than when they are cultivated, and small areas in large plantings may be set, although the soil is never so fertile nor the trees so productive as on the more level land.

As with soils, there are localities where extreme variations in the topographic components occur within small areas. A diagrammatic representation of an airplane photograph of an orchard on such a variable site is presented in Fig. 18 to show the pronounced differences in tree growth. Variable sites of this sort must be given a lower rating than the components would justify separately, because of the impossibility of setting compact orchards if the unfavorable spots are discarded, or of obtaining large acre yields if the eroded slopes are set.

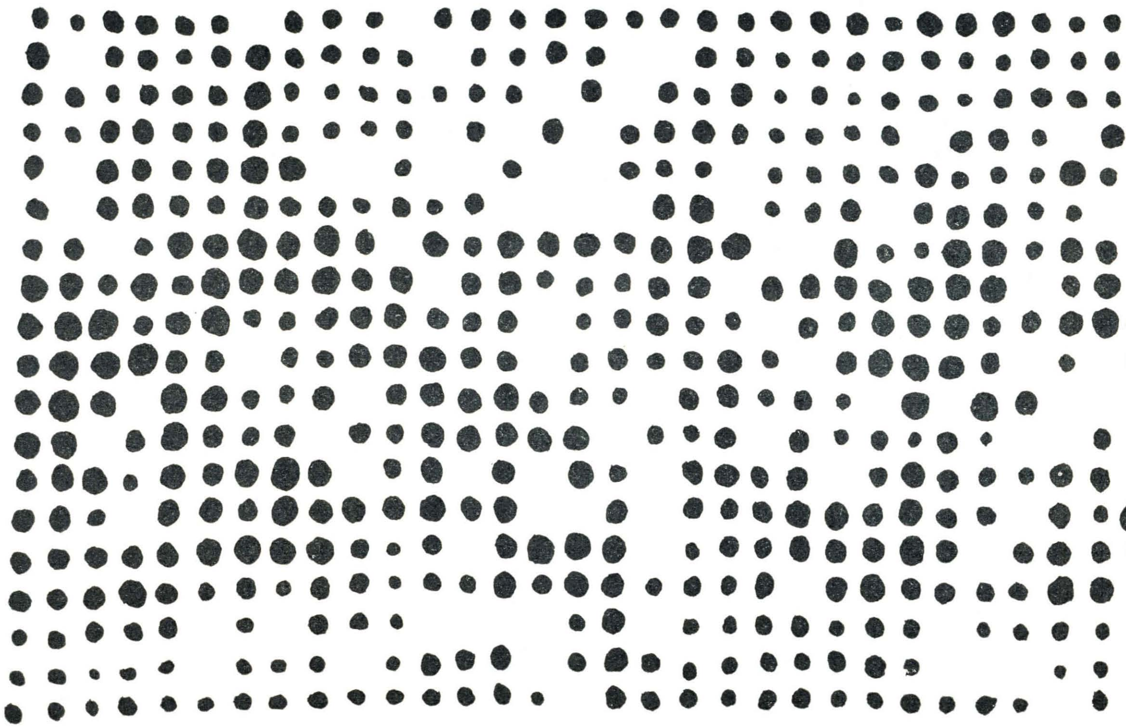


Fig. 18. Illustration of an orchard which has become unprofitable because the site is too variable
The drawing represents the comparative circumferences of the crowns of the trees, a fac-simile sk
photograph. The number of missing trees and great variation in growth of individual trees is striking
est growth and vacancies occur on steep, eroded slopes.

The Influence of Local Climate on Orcharding

Southern Michigan is bordered by Lake Michigan on the west and Lakes Huron and Erie on the east. These bodies of water exert a pronounced favorable influence, particularly along their shores, by moderating the cold waves of winter and reducing the number of destructive spring frosts. Consequently, the frequency with which injuriously cold

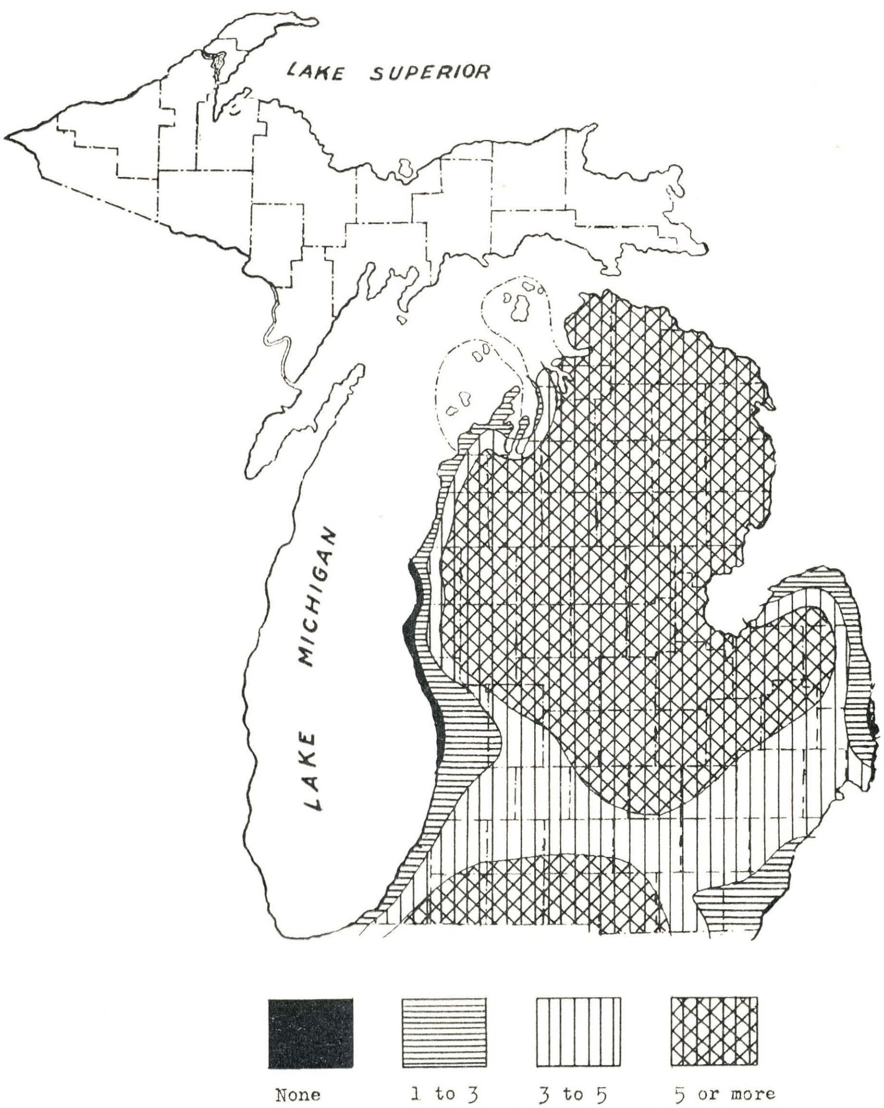


Fig. 19. Approximate frequency of years having injuriously low temperatures during the period 1920-21 to 1929-30. Owing to differences between the records of neighboring stations, the differentiation of clear cut areas cannot be made with absolute accuracy, but the map illustrates the general distribution of areas more and less subject to injuriously cold winters.

winter freezes and late spring frosts occur varies with the location within the state. The protection afforded decreases rapidly as the distance from the shore increases. The local climate characteristic of the interior of the state is relatively unfavorable.

Severe Winter Freezes—Growing tender fruits is hazardous where severe winters are frequent because of the loss of too large a proportion of the crops or the destruction of the orchard. The exact temperature which causes the loss of a peach crop will vary somewhat, due to slight differences in varietal susceptibility and to the condition of the trees at the time of the freeze; it is here assumed to be —12° F. More severe temperatures will cause wood injury on peaches and cherries and even the more hardy fruits, such as apples, are injured occasionally, particularly following years of heavy production or when the trees have not ripened their wood thoroughly. A map (Fig. 19) is presented which shows the approximate number of years in which a minimum of — 12° F. was reported by the cooperative stations of the U. S. Weather Bureau in southern Michigan from 1921 to 1930. The cold waves are more frequent and more severe in the northern than in the southern portion of the state, but some seem to swing around the southern end of Lake Michigan and cause low temperatures in the southern tier of counties. Since the degree of protection afforded by the lakes and the extent of their influence varies with the path of the cold wave and the intensity and direction of the wind, a map of this sort covering any other 10-year period would present a somewhat different appearance. Nevertheless, it illustrates quite clearly that severe winter temperatures are more frequent in the interior of the state than along the shores. Where the map indicates cold waves are more frequent, station records usually substantiate the map.

Spring Frosts—Proximity to the lakes also reduces the probability of injury to fruit crops by spring frosts, the quality of the sites being otherwise equal. The difference in the amount of growth made at any time in early spring and the difference in the blossoming dates for the same fruit is apparent between Niles and St. Joseph or between Shelby and Stoney Lake, for example. The date of the last spring frost is usually later for inland than for shore stations. Thus, the fruit trees near the lake shore usually have made much less growth at the time of the last killing spring frost than those inland, frequently enough less to permit the trees in the protected area to produce crops when inland orchards produce but scanty ones.

No method has been developed by which the differences in the number of destructive frosts at the different stations may be determined directly from the weather bureau data, since no measure of the advancement of vegetation is recorded. Nevertheless, the amount of growth may be measured roughly, for comparative purposes, by noting the days on which, and the extent to which, the maximum temperatures exceeds the point at which growth occurs. An approximation of this sort is given in Table 1 where summations of the maximum temperatures above 42° F. have been calculated from midwinter to the last severe spring freeze. Owing to the variations reported by neigboring stations due to the differences in their surroundings, it is impossible to present a map for illustration. These data are open to

Table 1. Sum of daily maxima above 42° F. from Feb. 1 to last date in spring when minimum of 29° F. or lower was recorded.

Year	St. Joseph	Bloomingdale	Kalamazoo	Jackson	Monroe	Grand Haven	Lansing	Port Huron	Ludington	Hart	Big Rapids	Harbor Beach
1920........	351	758	342	683	415	200	549	371	319	699	701	446
1921........	728	697	739	812	857	462	643	540	341	1,070	1,173	585
1922........	201	648	690	867	785	432	618	410	277	427	421	416
1923........	151	673	808	988	1,025	58	776	521	389	575	637	518
1924........	105	*	533	221	268	92	451	116	212	688	698	101
1925........	250	1,455	1,573	1,365	473	239	1,234	303	147	1,250	1,140	382
1926........	286	488	504	603	408	224	415	336	162	861	940	269
1927........	271	583	576	793	800	432	560	441	342	600	526	286
1928........	340	807	380	508	675	290	385	345	204	765	316	465
1929........	72	599	614	921	787	365	553	264	91	737	706	899
No. times 600 exceeded	1	6	5	8	6	0	4	0	0	7	7	1

criticism because the summation does not measure growth exactly nor do the minimum temperatures have great significance unless the local topography and surroundings of the stations are considered. The differences are large enough, however, to offer a basis for a comparison of the general frostiness of sites along the shore and inland.

Assuming that an accumulation of more than 600° before the last occurrence of 29° F. will result in damage, the following comparisons may be made: The shore stations reported unfavorable conditions as follows: Grand Haven, Ludington and Port Huron, none, and St. Joseph and Harbor Beach, once each. On the other hand, these interior stations reported such conditions more frequently: Lansing, four times, Kalamazoo, five times, and the others even more frequently. Even should the assumption in regard to the amount of temperature accumulation that is usually injurious be inaccurate, and notwithstanding unmeasured variations in local topography the relative records of the shore and inland stations differ sufficiently to indicate the superiority of sites near the shore, other things being equal. Mention should be made that high dune ridges along the shore reduce the protection afforded by the lakes against spring frosts in the lee of the dunes.

Air Drainage—Even though the frost hazard be less along the shore, the local frostiness of projected sites should be evaluated before the orchard is set. Of course, this consideration is especially important in the interior of the state. Frosts occur on still, clear nights, when the cold air tends to settle into depressions, and are more rare on slopes and adjacent uplands than in hollows surrounded by higher ground. Wide plains with no pronounced hills and valleys are intermediate in frostiness, but should not be utilized for fruits especially subject to frost damage, such as cherries and grapes. The accumulation of the cold air at lower levels accounts for the relatively higher temperature on the uplands and slopes, consequently, the area of low land must be of sufficient size to receive the large quantity of chilled air that accumulates during the night if frost is to be avoided on the higher ground. The more extensive the low land, the lower the elevation may be and still avoid frost. On very broad plains, gentle ridges with unobstructed slopes whose elevation does not exceed 25 or 30 feet above the plain may prove to be as free from frost as much higher hills surrounded by narrow valleys. Crops very sensitive to spring frosts should be avoided on all inland sites except the most favored and set on them only when local marketing conditions are sufficiently favorable so that the higher price received will compensate in large part, at least, for the damage that will occur from time to time.

Sites of this type are also relatively warmer than low lands during severe freezes when there is little or no wind.

Summary

No single factor should be considered to the exclusion of others when evaluating a prospective orchard site. Soil, topography and climatic conditions are all of great importance, as well as the local market. These factors are all variable in Michigan, and sites are relatively rare where all are very favorable for orcharding. Although such sites have a decided advantage under competitive marketing, which makes large and regular production essential, many profitable orchards are found where a single factor is only moderately favorable, the other two being especially favorable. It is probable that sites of these two classes are of sufficient acreage to supply all the fruit demanded by Michigan markets; hence less desirable sites should not be set.

In considering the value of different soils for orcharding, their ability to supply moisture during extended drought is probably of first importance. The texture of the soil which determines the amounts of available moisture it may hold and the structure, which permits or prevents the penetration of roots to the moist regions of the subsoil, are both significant. Since the acre requirements for water vary between different fruits, it is possible to select those best adapted to the particular soil. In general, well-drained loamy soils, underlaid by till clay of gritty texture and relatively open structure rank first. Sandy hardpans, water-logged, imperfectly-drained subsoils, hard, impervious underlying clay, and deep dry sands all delay or prevent the penetration of roots to the underlying moist subsoil. Deficiencies or oversupplies of single elements, other than a deficiency of nitrogen, are infrequent. The surface layers contain more available mineral elements necessary for plant growth than do equal amounts of subsoil; hence, soils where the darker colored upper layer has been removed, is thin or depleted by continuous cultivation, are of low fertility. Fruit trees succeed best on soils of moderate fertility.

Topography is of importance mainly as it influences erosion and the frostiness of the site, although the increased cost of orchard operations on abrupt slopes may become a considerable factor. Erosion removes the more fertile surface soil and fertilization is seldom able to correct the resulting deficiencies since such applications are removed by subsequent washing. Orchards are seldom, if ever, profitable when set on slopes already denuded of top soil, and are frequently destroyed on steep slopes by subsequent erosion induced by the cultivation of the orchard. Sod cover reduces erosion to the greatest degree, but its use is not feasible except with certain fruits set on the best soils. The greater the slope, the more unfavorable the site for orcharding.

The climatic factors of greatest importance to orcharding are the frequency with which injuriously low temperatures occur during the winter (especially for peaches) and the number of years in which late spring frosts or freezes reduce the crop (especially for cherries). Length of growing season, which decreases toward the north, is important in choosing the varieties, particularly of grapes, apples and peaches. Winter temperatures in the interior of the state are lower than those along the lake shores at the same latitude. Late spring frosts and freezes are more frequent and destructive away from the shores than near them, since growth is more advanced in the warmer interior and the last frosts usually occur later in the season there. The belt along the shore where freezes and frosts are relatively infrequent is narrow, its width varying from place to place and from year to year. The nearer the site to the lake, no dune ridge intervening, the greater the probability that regular crops will be produced. A decided increase in the frequency of injury occurs within a few miles of the shore.

The hazard of spring frost damage is reduced greatly by selecting elevated sites where the heavy, chilled air has an opportunity to settle into adjacent extensive areas of lower ground. Although the selection of such sites is important even near the lakes, it is essential in the more frosty interior portions of the peninsula.

Orchard sites are numerous where any one or all of the soil, topographic or frost factors vary markedly within narrow limits. Such sites must be rated lower than the sum of the constituents would appear to warrant, since it is impossible to adjust the planting to the site and make a compact unit. Either irregular unplanted areas must be left, thus making orchard operations more difficult, or some of the trees set are destined to be unproductive and reduce the average acre yield, although they must receive the same care.

The best orchard sites, where profits are most likely to be obtained, are those on broad ridges or upland plains bordering depressions, or loamy soils underlaid by gritty clay of relatively open structure, located within three or four miles of Lake Michigan. Sites of second grade but still rather favorable, especially where local markets are good, are those where only a single one of the three factors enumerated above is somewhat less satisfactory. Other sites should not be utilized for new orchard plantings, at least under present economic conditions.