Battenfield & Berney. 1984. Biological Monitoring in Apple Orchards: An Instruction Manual.

Apple Tree Growth & Development

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INTRODUCTION

A tree is a complex perennial plant whose growth is affected by internal and external events. External events include temperature, rainfall, humidity, fertilizers, growth regulators, pruning, pesticides, and damage (physical and biological). Internal processes include photosynthesis, carbohydrate production, flower bud initiation, dormancy, winter hardiness and all other growth activities. A tree responds to what happens to it. For instance, it responds to sunlight and warm temperatures in the spring by breaking dormancy (its winter sleep) and opening its leaf buds to begin photosynthesis. Photosynthesis provides the building blocks for growth.

A tree also responds to damage. For example, leafrollers and mites feed on leaves. By destroying leaf surface, they reduce the tree's photosynthetic ability. Because photosynthesis is needed for all growth processes, reduced photosynthesis means less growth. Too much damage to a tree can leave it weak and therefore more vulnerable to attack by other pests or more susceptible to winter injury. Damage can be environmental (too little rain, too cold, etc.), biological (pest damage to leaves, roots, bark, branches, fruit, etc.), and physical (injury from tree shakers, excessive pruning, over fertilization, etc.).

These same factors (good and bad) affect the tree the following year. For example, if a tree has been completely or partially defoliated one season, either from insect pests or chemicals, it will have used up most of its carbohydrate supply, which it produced from photosynthesis. If it survives the winter, it will have few carbohydrate reserves to begin growth in the spring. If it does resume proper growth, it will not produce a good crop yield because it won't have the proper resources; the tree is weak, and it could be more vulnerable to further damage. If it recovers that season, even though it may yield less fruit, it still may not produce as abundantly the next season.

LIFE CYCLE

Apple trees live for over 40 years, and as with all living things, they are in a constant state of change. Their major growth phases are propagation and juvenility, vegetative development, maturity, and senescence.

PROPAGATION AND ESTABLISHMENT

This life phase lasts two years. Propagation is the growth of a tree from seed or from a scion (fruiting portion) and a rootstock (root portion). Scions are chosen for fruit and tree growth; rootstocks are selected for anchorage, size control, pest resistance, and environmental conditions such as temperature, soil, and moisture.

Before variety and rootstock selection and planting, a grower needs to be looking ten years ahead to when the tree will be full-bearing—what are the needs for that variety (quality, market/consumer acceptance, pest resistance, and vigor)?

Although non-bearing trees do not flower or bear fruit, they still must be cared for and protected from pest damage to keep the tree healthy. Decisions made now could influence future development of the tree, fruit yield, and value.

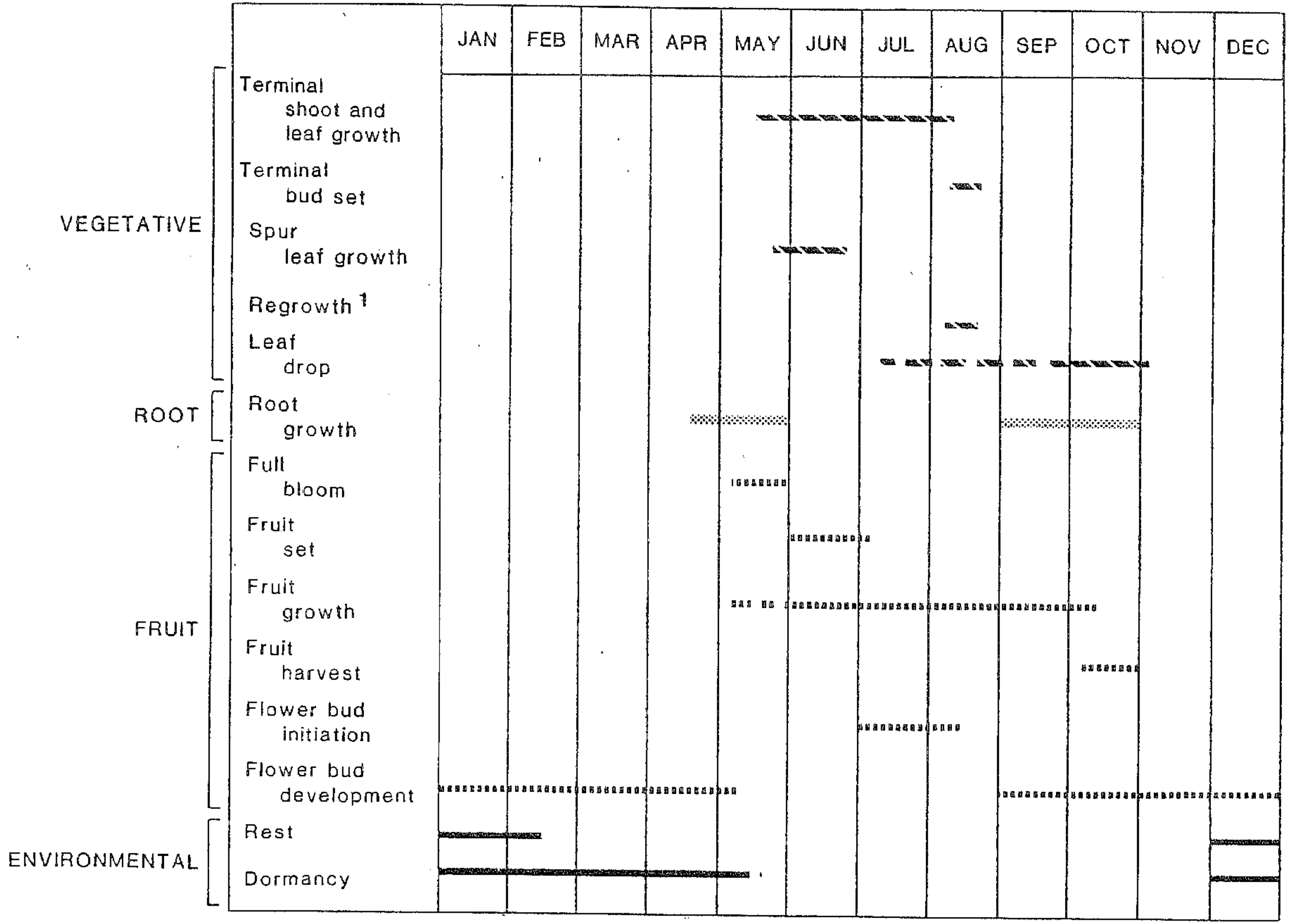
VEGETATIVE DEVELOPMENT

This is the "formative" stage of a tree's growth, and it lasts four to ten years depending on the apple variety (something like the pre-school years for a child). Whatever happens to the tree, as with a child, now will affect it for most of its life. Therefore, pests that feed on the leaves, shoots, spurs, bark, and roots can harm the tree's growth, potential for bearing, and health. And as with all things, a balance must be maintained. For instance, vegetative growth is necessary for growth and photosynthesis, but too much growth delays fruiting and flowering. Excessive early flowering and fruiting restricts vegetative growth.

During this time, the tree canopy is formed. Vertical branches can be trained to grow horizontally so that the tree has wide crotch angles, which allows early cropping and good light penetration and durable structure.

MATURITY

The tree is now bearing fruit and must



Yearly growth cycle of apple trees in Michigan. The lines represent the approximate time when particular life stages begin and end. Because apple varieties develop at different rates, this chart only gives a general picture of growth times.

(J.A. Flore)

be protected from pests that would harm vegetation or fruit. How long a tree remains productive depends on the crop, the cultivar, and sometimes the environment. This stage is discussed in depth, under Annual Life Cycle.

SENESCENCE

This is old age. The tree is past its peak production years, but it may still be useful.

ANNUAL LIFE CYCLE

Each year, a tree goes through a regular sequence of growth events (see chart). Temperature, rainfall, light (day length), and humidity determine when a tree begins growing in the spring and how long each growth stage lasts. The timing of the various seasonal stages also depends on variety and rootstock. Temperature is the most important because it tells a tree when to break rest, when to bloom, when to fruit, and when to prepare for dormancy. It also regulates pests--when they occur and sometimes in what quantity.

VEGETATIVE GROWTH STAGES

Terminal shoot and leaf growth begins in late May and ends in mid-August. Terminal shoots are located at the end of branches. Shoot growth expands the canopy and allows new buds and leaves to grow, which increases photosynthetic activity. Most new shoot growth in the form of lateral buds occurs early in the season. As the season progresses, the tree's energies center more on increasing girth and developing vascular tissue (the tissues that carry sap and nutrients throughout the tree). As more vascular tissue develops, the bark and wood mature.

Terminal bud set begins in early August and ends in mid-August, depending on variety and location. Terminal buds are found at the end of branches.

Spur leaf growth begins the same time as terminal shoots, but stops around the end of June. They are short shoots found laterally on branches. Most fruit develops on fruit spurs, which are short shoots found on fruit trees. Large, thick spurs develop many leaves and are correlated with large, well-colored fruit. Fruit spurs exhibit a zigzag growth pattern while non-fruiting spurs tend to grow straight. This is from the fruit growing on the terminal portion of the spur. In some varieties of apple, fruit spurs bear every other year.

Regrowth is caused by optimum environmental conditions following some stress and does not happen every season. It happens between late July and September.

Leaf drop begins around the first of October through mid-November.

ROOT GROWTH STAGE

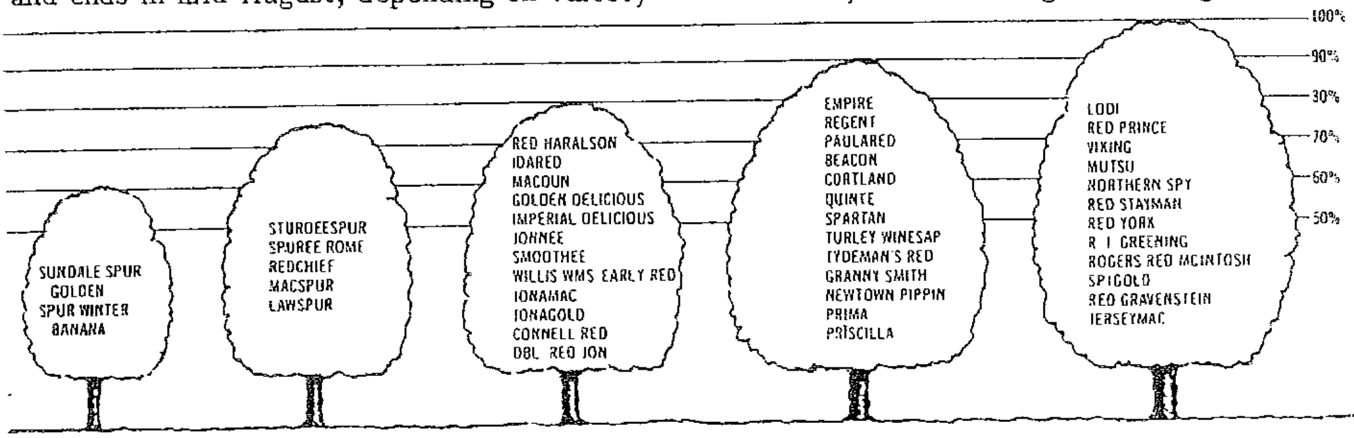
Root growth begins after dormancy around mid-April and lasts until bud break, then resumes again after bud set. Roots are the first part of the tree to resume growth after dormancy.

FRUIT GROWTH STAGES

Full bloom begins in early May and lasts only a few weeks, ending around the end of May.

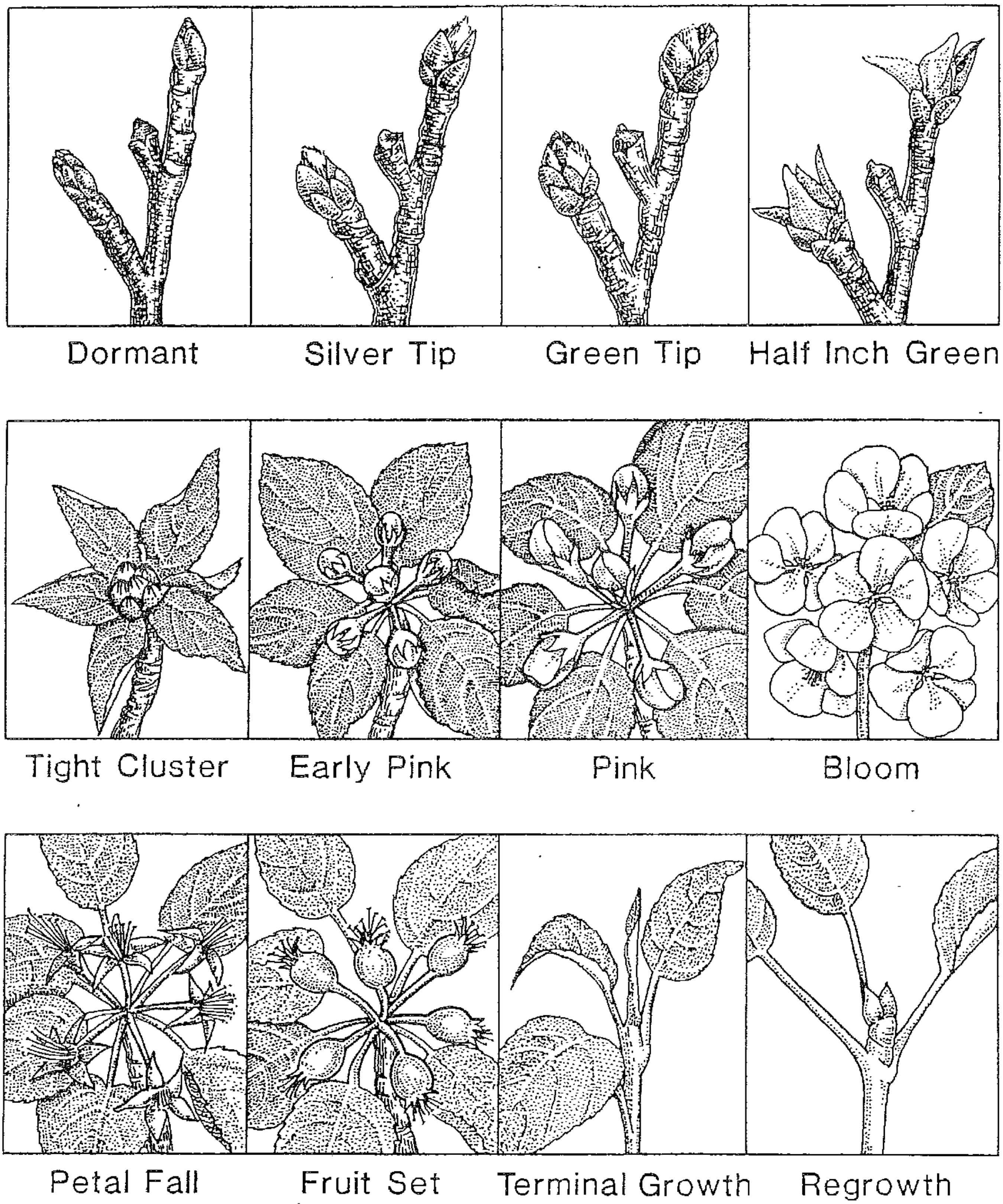
Fruit set follows full bloom and lasts until early July.

Fruit growth depends on variety; some show signs as early as the first week in May. Most fruit growth can be seen starting in early June after full bloom and lasting until mid-October. During bloom, the cells that will form the apple divide rapidly. This is followed by a cell enlargement stage, which



Comparative sizes of most apple varieties. (Used with permission of Hilltop Orchards and Nurseries, Inc.)

APPLE GROWTH STAGES



occurs after fruit set. The size of the apple at harvest is determined by the number and size of these cells. Generally, larger apples have more cells of greater size.

Fruit drop may occur all season, but one distinct period begins a few weeks after petal fall and continues for two to four weeks. This drop, usually due to lack of pollination or self-fertilization, is called "June drop."

Fruit harvest usually goes from August through October, depending on variety.

Flower buds for the following year are begun between the mid-June and August. They grow on the end (terminal) of shoots or short spurs.

Flower buds begin developing after initiation in early August. These buds will be the flowers and potential fruit crop for the following year. Their development does not stop during the winter when the tree is dormant, but continues through spring until bud break and the familiar stages of silver tip, green tip, half-inch green, tight cluster, pink, full bloom, and petal fall.

DORMANCY AND REST

Dormancy (characterized by lack of leaves and no visible signs of growth) is necessary for trees because it protects them from winter cold and freezing injury. In Michigan apple trees, dormancy begins in early December. Decreasing temperatures and shortening day length (photoperiod) cause the tree to enter a state of "rest" where leaf buds, flower buds, and shoots are unable to grow. No photosynthesis occurs during dormancy. Rest is important, because during this time the tree cannot be forced into growth by warm spells in the middle of winter, which could kill the tree if followed by severely cold periods. Rest is terminated after buds are exposed to chilling temperatures for a given length of time followed by temperatures favorable for growth. In Michigan, this occurs around early February. Temperatures of 0^{o} to $5^{o}C$ for 1200 to 1500 hours are sufficient to break rest.

PHOTOSYNTHESIS

Photosynthesis is the process by which leaves absorb carbon dioxide, combine it with water, sunlight, and chlorophyll, and change it into carbohydrates. Minerals, absorbed by the roots, are later combined with the carbohydrates to form proteins and other plant foods that are used for tree growth. Leaves are the primary source of photosynthesis. Therefore, the more healthy leaf surface on a tree, the faster it will grow. Most photosynthesis occurs while a leaf is growing; as a leaf ages, its photosynthetic capability decreases.

The shoot and root systems supply the tree with food. Each component, except the reserves, requires a certain amount of carbohydrate to maintain its particular biomass. If the carbohydrate resource declines, biomass decreases; if the carbohydrate resource increases, biomass may increase.

Stored reserve materials are distributed throughout the stems and roots, but are mainly concentrated in the roots. These reserves maintain the tree through winter and spring when photosynthesis is either zero or at a low level. Reserves also supply the energy and the building materials for new growth in the spring.

POLLINATION

Without sufficient pollination and carbohydrates (food), although a tree flowers, it will not produce fruit. The flower must be pollinated so that it will develop into a fruit. If little or no pollination occurs, the flower will either drop or develop a small fruit that usually drops prematurely. Almost all apple cultivars require cross-pollination from another cultivar, but even when not required, cross-pollinated fruits are of better shape, size, and color than fruits obtained through self-pollination. The primary agent of pollination is the honeybee, which pollinates over 90% of apple blooms.

Bees transfer pollen from the pollinizer tree to the main cultivar. To insure a sufficient pollen supply, the pollinizer should flower (bloom) one to two days before the main cultivar blossoms and the pollen should be compatible (triploid varieties, like Rhode Island Greening, cannot be pollinizers). If limited or no pollination occurs, the flower will drop or develop a small fruit that usually drops prematurely. Even in varieties that are self-fertile and do not require a pollinizer variety, bees transfer pollen from the male to the female flower parts. Without this movement, fruit set would not occur.

A common question asked by growers concerns how large the bee population needs to be to insure adequate pollination. Usually the native bee population in the orchard is too small because of pesticide use and lack of

Table 8. Events and organisms that increase or decrease bee activity and pollination in an orchard.

Who	What	Action
Plants on orchard floor, like dandelion	Can attract bees, especially when temperatures are below 60° F, because bees then fly closer to the ground	Remove competetive plants
Understory, like clovers	Can attract bees; if blossoms get drift from insecticides and bees forage on, could kill bees	Remove
Temperatures under 50° F	Bees do not fly; nectar is not secreted	None
Wind	Bee activity drops as wind increases	None
Relative humidity	With high relative humidity, nectar becomes diluted and less attractive	None
	Low humidity concentrates nectar and increases its attractiveness	None
Light intensity	High light intensity increases bee activity, cloud.cover decreases bee activity	None

nesting sites; therefore, honey bee colonies need to be brought in. The number of colonies per acre necessary for sufficient pollination depends on tree size, flower density, orchard design, colony strength, competitive plants, and weather before and during bloom. Orchard mapping helps determine the number of hives needed.

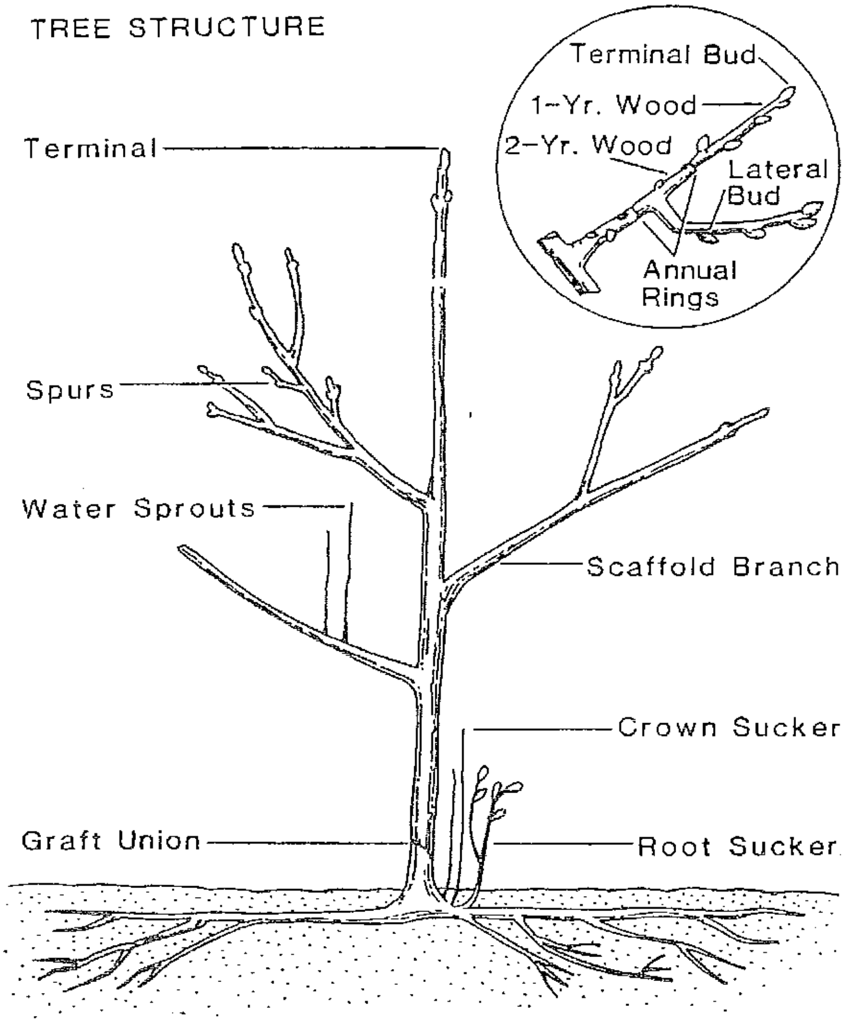
For cross-pollination and fruit set to occur, compatible pollen must be deposited on the blossom's stigma. One way is to make bees compete with one another for a tree's nectar; this forces some bees to move to other trees; pollen is then transferred from tree to tree. If the transfer is between different varieties, fruit can be set. The percentage of bees moving off the pollinizer to the main cultivar depends on the orchard's design. Honey bees generally move to the next tree in a row, rarely crossing between rows.

Another, and possibly more significant means of cross-pollination, may be in-hive pollen transfer. In the hive, bees continually brush against each other, and probably unwittingly exchange pollen. Consequently, honey bees may be leaving the hive with pollen on their bodies from species and varieties that they never visited. This would explain why fruit set occurs in solid block plantings of self-incompatible trees or where pollinizer trees are far from the main cultivar.

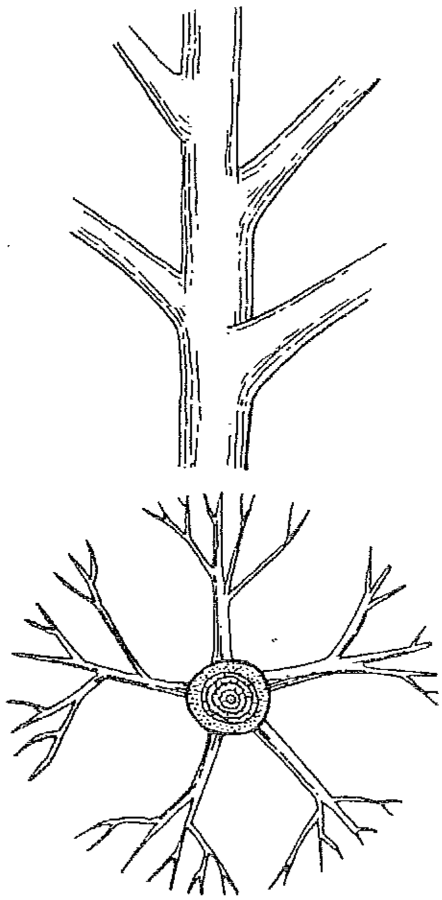
Constraints on in-hive pollen transfer involve weather, colony strength, and the availability of compatible pollen. Colony strength is measured by frames of brood and adult bees. Overwintered colonies are always stronger (contain more bees and brood) than packaged bees and have a larger foraging population. About one-third of a hive's population usually are foragers. The percentage of the foraging population that works apple depends on the density of apple bloom and the presence of concurrently blooming competitive plants (such as dandelion and yellow rocket) in the orchard (see Table 8 for a list of what affects bee activity). Fewer bees forage on apple before and after peak or full bloom. Apple is not a competitive nectar source, and bees like to stay with a nectar source that is rewarding.

Honey bee flight activity and pollination are the result of interactions of weather, colony, and orchard conditions. A computer simulation model of the pollination system, now being developed at MSU, is a way to measure these interactions so that fruit set can be predicted during and immediately af-

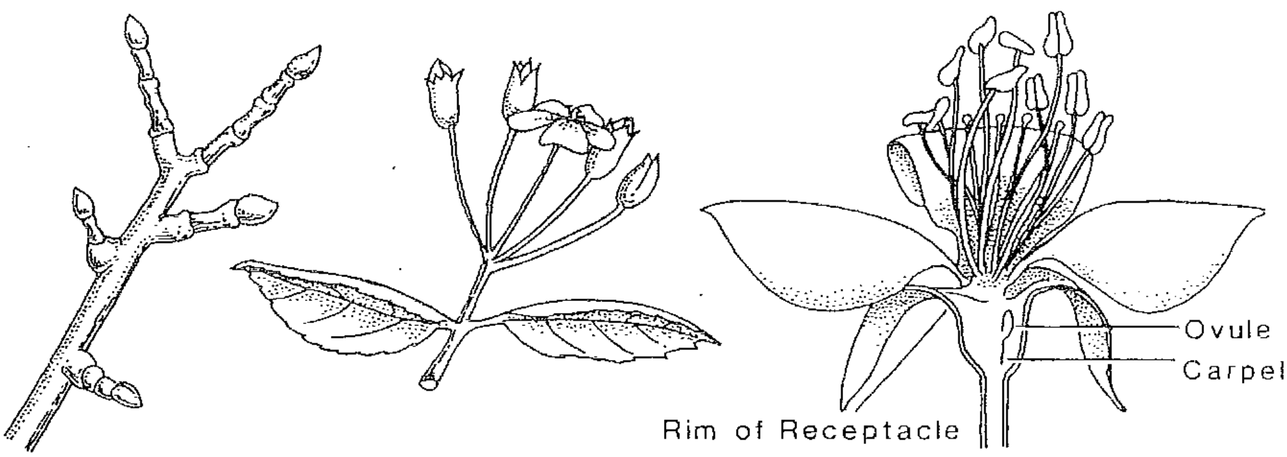
TREE STRUCTURE



WELL SCAFFOLDED TREE



APPLE FLOWER BUDS ON 2-YEAR AND OLDER SPURS



ter bloom. By using this model, growers can decide if it will be profitable to protect the fruit for the fresh market or maintain it for processing. This information can be used to determine the need for thinning sprays and predict when adequate pollination has occurred during bloom so that colonies can be removed to avoid oversetting of fruit. The pollination model can predict the number of colonies needed to insure adequate pollination (see Table 9 at the end of this chapter).

LIGHT

Sunlight is vital for the growth and development of any plant. Without light, photosynthesis cannot occur and plants cannot grow or produce sufficient carbohydrates (food) to sustain themselves. In apple trees, sunlight affects photosynthesis, leaf structure, fruit bud formation, fruit growth, fruit coloration, and yield. A minimum level of light must reach all leaves to drive the photosynthetic processes which convert sunlight to the carbohydrates needed by the tree for growth, maintenance, and fruit production. An important aspect of light is its intensity, which governs the rate of carbohydrate manufacture in an individual leaf. Structure of individual leaves thus varies depending on the light conditions under which each leaf develops and grows. Leaves on fruit spurs in particular need lots of light because these leaves manufacture most of the carbohydrates that are used to form the neighboring fruit.

The way light comes into and is distributed in a tree can be controlled by tree spacing, tree size, shape, and pruning. Winter and summer pruning will insure adequate light penetration. Within-tree illumination is greatly aided by increasing the distance between framework branches. Moderate thinning and opening tree crowns also increases light penetration.

Changing the crown in mature trees that are shaded may increase yield of quality fruit. Improving light intensity has increased yields when the leader and main branches are selectively removed by pruning.

Pruning growing shoots in the summer increases light intensity, which benefits red coloration and stimulates fruit buds to form. Summer pruning can also benefit productivity by exposing spur leaves, which increases photosynthesis.

PRUNING

Pruning is used to shape trees, remove excessive twig growth, remove water sprouts, and increase light interception. Pruning also can be used to remove dead, diseased, or insect-infested wood, which will reduce pest populations the following year and increase tree vigor. Tree canopy and structure can alter the environmental conditions to which a pest is subject. For instance, proper pruning facilitates air movement and allows a tree to dry quicker after a rain. This, in turn, can reduce the incidence of certain diseases, such as apple scab, bitter rot, and sooty blotch fungus. While a tree is maturing, selective pruning can be used to remove criss-crossing, drooping limbs, and poor crotch angles. When a tree is at the desired size, regular pruning restricts further expansion and allows better light penetration to interior leaves.

Most pruning is done in winter and early spring when total tree growth is least affected. Dormant pruning is invigorating, so if a tree is pruned too early in winter, such stimulation could cause the tissues to lose their hardiness and could result in freezing damage. However, a tree will not be hurt if pruning is continued through bloom. Pruning past bloom, however, can decrease tree vigor because it removes leaf surface necessary for photosynthesis.

The tools used for pruning should be sharp so that cuts are smooth and clean. Ragged cuts heal slowly and poorly. Tools should also be cleaned frequently to minimize the possibility of transmitting harmful organisms, like diseases.

If too much foliage is lost due to excessive pruning, the roots send large quantities of nutrients and water to the remaining structures of the tree, which results in considerable shoot growth and water sprout development. This excessive vegetative growth can contribute both physiologically and environmentally to outbreak population levels of certain pests.

Properly pruned trees will not only produce greater yields, but the fruit will have better color and size, and the tree will have greater vigor.

THINNING

Thinning is a practice by which part of the fruit crop is removed before it matures on the tree. Fruiting exhausts a tree's resources; therefore, the goal of thinning is to remove a portion of the fruit to conserve sufficient nutrients and carbohydrates for good shoot and spur growth, leaf development and flower bud formation for next year's crop and to mature the current season's crop.

Thinning increases annual yields of marketable fruit; improves fruit size, fruit color, and eating quality; reduces limb breakage; promotes tree vigor; and reduces alternate bearing tendency.

In Michigan orchards, two methods of thinning are used: hand and chemical. In hand thinning, fruit are pulled or broken off by hand. Chemical thinning reduces the amount of hand thinning needed; however, it can result in overthinning, hazard of frost from early sprays, some foliage injury, and variable results due to tree age, vigor, and timing of application.

VIGOR

All pests collectively influence the long-term health of a tree. Indirect pests can adversely affect all organs of the tree; however, direct pests that feed only on fruit do not diminish tree vigor. The greater a tree's vigor, the stronger is its resistance to pest attack and injury from cold.

Fruit trees are in good vigor if leaves are large, plentiful, and dark green. Thick and relatively long shoots, regular fruiting, and satisfactory fruit size and quality are also good indicators of healthy tree vigor. Trunk and scaffold limbs should be thick and stocky with dark, greenish-brown color and only a moderate amount of bark scaliness. Additional indicators of vigor are the amount of growth and the number of leaves on spurs.

PESTS

If all pest attack on fruit was eliminated, fruit quality and yield could still be reduced if indirect pest attack (to leaves, shoots, roots, etc.) was high. Extremely high levels of indirect pest attack can kill a tree because the tree will be unable to accumulate carbohydrates. Minimal feeding by indirect pests, however, may not damage the tree's fruit production or vigor. Sometimes, pest attack may actually result in greater fruit production in subsequent seasons or more stable fruit production.

Pest attack, however, is not the only stress applied to fruit trees. Temperature and rainfall also stress the tree.

Any interruption in the photosynthetic process during the growing season (leaf loss from pest attack or premature defoliation) reduces the manufacture of carbohydrates, which leads to fewer food reserves in the tree for winter and spring. Premature leaf loss may also decrease winter hardiness.

Healthy leaf activity is vital to tree growth, flowering, and fruit development. Therefore, during a tree's early growing season through June, pests that destroy leaf surface should be carefully monitored and controlled. Later in the growing season when carbohydrates are used mainly for stem and root growth, fruit enlargement, and carbohydrate accumulation, higher populations of foliage-feeding pests can be tolerated.

GROWTH REGULATORS

Plant growth regulators are organic compounds that influence growth, development, and maturation of vegetative and reproductive plant structures. The degree and type of response varies with the type and concentration of chemical, the crop, and the stage of plant development when applied. Before applying a growth regulating compound, a grower should know how it will affect the tree and crop and what side effects might occur.

Growth regulators are systemic and must be absorbed into the plant. Therefore, because leaves and fruit are the primary absorbing organs, any factor that influences the initial contact of the chemical with the plant or its absorption may change its response. Also, the environment before, after, and during application may influence chemical performance. Factors that increase absorption (high temperature, slow drying, healthy foliage) will increase the response, and those factors that decrease absorption (fast drying, cool temperatures, injured foliage) will decrease the response. A grower should exercise caution when deciding on whether or not to use growth regulators on plants low in vigor or those under stress, since these plants often over-respond. (For greater detail concerning growth regulators, see the chapter on Plant Growth Regulators in the 1984 Fruit Pesticide Handbook.)

PESTICIDES

To make sound management decisions, a grower should have as much information on

Table 10. Apple rootstock varieties and their characteristics.

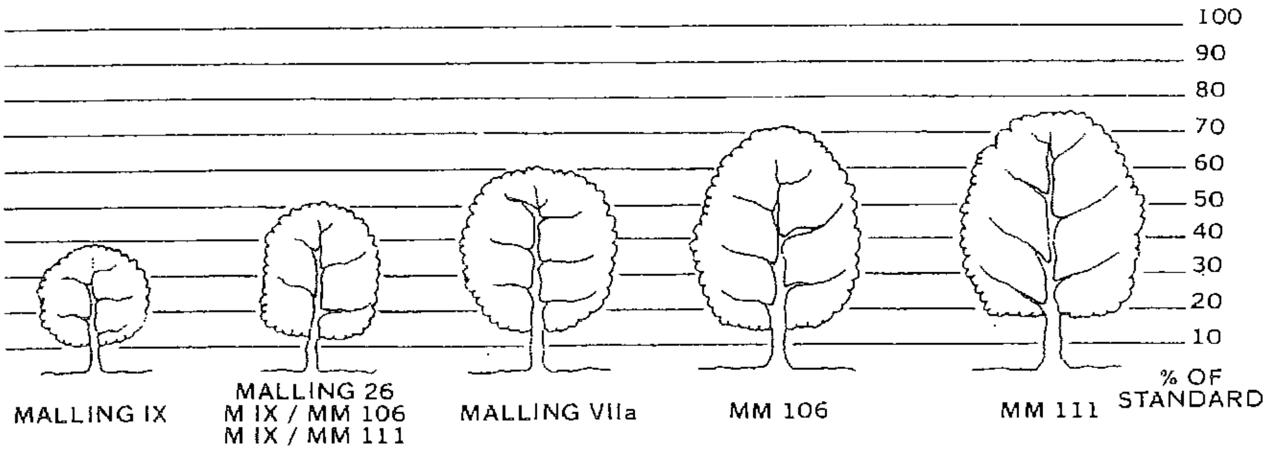
Variety	Characteristics
M9	(-) very brittle roots, must be staked (-) very drought sensitive, must be irrigated
MM106	(-) does not take to heavy soils (-) does not grow well in perched water tables (-) susceptible to phytophthora root rot (-) susceptible to union necrosis
M26	(-) does not take to heavy soils (-) does not grow well in perched water tables (-) extremely susceptible to phytophthora root rot (-) extremely sensitive to droughty conditions (-) susceptible to fire blight
M7 and M7a	(+) adapts to wide range of soil conditions (-) does not readily establish roots; non-radial system may develop roots only on one side of tree; over time, tree will lean (-) inadequate anchorage (-) problem with suckering (+) tolerant to phytophthora
MM111	(+) drought tolerant (+) deep root system (-) large and vigorous

the positive and negative points of any chemical that may be used in an orchard. Many pesticides used on apples significantly affect pollination, fruit-set, and other physiological processes. For example, spray applications during bloom can not only harm honeybees, and therefore the fertilization process, but can also directly or indirectly reduce fruit-set either by reducing pollen viability or by reducing stigma receptivity. Fungicides containing sulfur may reduce fruit-set by injuring the flower and may reduce the photosynthetic rate. Lime-sulfur is toxic to apple trees and reduces photosynthesis, which can dramatically reduce apple yields. Flotation-sulfur reduces leaf chlorophyll content and fruit size and causes poor fruit color. Captan or binapacryl sprays can inhibit apple pollen germination and pollen tube germination. They could also decrease fruit-set if sprayed during blossom when conditions for natural pollen transfer are adverse. Copper oxychloride, lime-sulfur, ziram, zineb, demeton, captan, BHC, dinocap, dicofol, nabam, and dichlone reduce pollen germination or pollen tube growth. Monuron, Atrazine, and simazine may decrease photosynthesis, as do Ryania and Guthion.

ROOTSTOCKS, SOIL, AND INTERSTEMS

The original purpose for using rootstocks was to propagate a desirable fruit variety and maintain tree to tree uniformity in production and quality. Horticulturists, however, found that rootstocks can control tree size and can help a variety become more tolerant of adverse soil conditions, insects, and diseases (see Table 10).

The condition and profile of the soil has a lot to do with how well the rootstock and tree will grow. Roots need space to grow to anchor the tree; they need soil to retain moisture and provide necessary oxygen and nutrient holding (cation exchange) capacity.



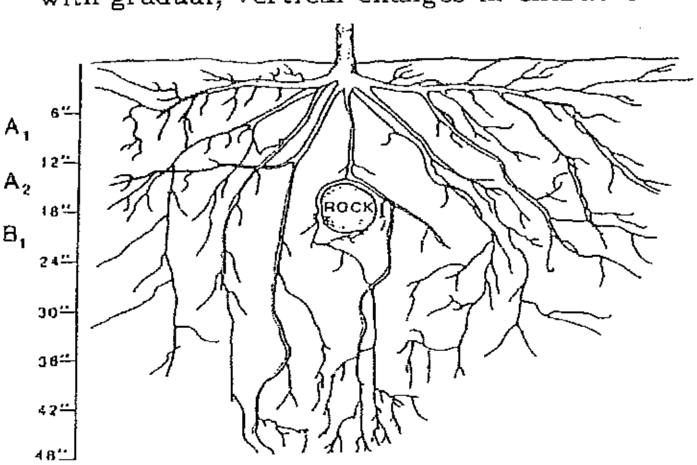
Sizes of trees on various rootstocks.

Rootstocks vary as to how they perform in different soil profiles.

A soil profile refers to the vertical cross-section of the soil from the surface into underlying unweathered material. A profile is made up of three layers, or horizons: A, B, and C. A horizon (topsoil) is the surface layer where components have been removed. B horizon (subsoil) is the part of the profile where materials from the A horizon have accumulated (iron, aluminum, lime, and colloids). C horizon is the geological substratum and, in Michigan, consists of unconsolidated mineral deposits of glacial origin: pure sand; sand; sand and gravel; friable sandy clay; silt to compact, massive, nearly pure, clay.

In Michigan, the characteristics of the B horizon can change drastically, both vertically and horizontally, from one tree to the next. Therefore, a grower should take extensive soil samples to determine the character of the soil. A desirable orchard soil profile possesses a deep, uniform, A and B horizon with gradual, vertical changes in characteristics, thus root development is enhanced and roots can forage the full depths for nutrients and water. The physical characteristics of the soil profile has caused many stressed trees in Michigan orchards. Stressed trees may be caused by limited root development due to excessive moisture, which reduces soil oxygen and enhances disease-causing root-rots, or from a lack of moisture which can cause drought stress. There are generally, three soil scenarios that limit root development:

1. Panned soils with dense, compact, or cemented subsoils or layers (claypans, hardpans, fragipans).
2. Fine-textured soils with poor internal drainage throughout the profile.
3. Layered or stratified soils where abrupt, significant changes in soil texture may disrupt water movement in the vicinity of the interface.



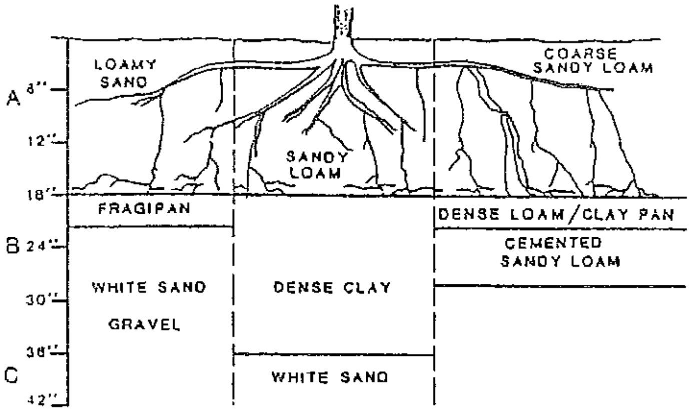
Desirable orchard soil and root distribution.

PANNED SOILS

A layer of compacted material at 10 to 18 inches deep can develop as a result of annual plowing (plowpan), equipment travel, or natural accumulation of fine particles (claypan) from the A horizon. A dense sand, gravel, or mixed layer also can develop from natural cementation (fragipan) and, like the above-mentioned layers, not only restricts root growth, but can inhibit water penetration, resulting in a perched water table. During dry periods, shallow-developed roots will not be able to get moisture, and the tree will show symptoms of drought stress.

FINE-TEXTURED SOILS

Root development may be limited in soils, known as "heavy," containing large percentages of clay and loamy clay particles

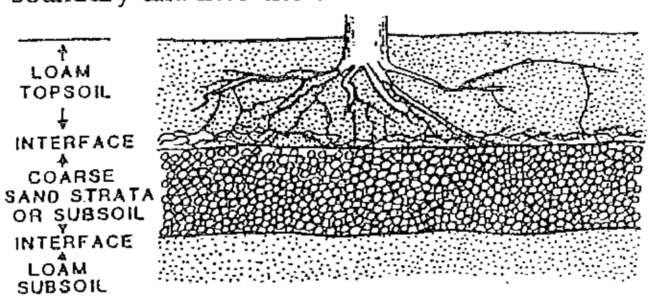


Three examples of soil horizons that result in panned soils.

throughout the A and B horizon. Proper rootstock selection can help avoid problems. Root growth is limited because of a lack of air pore spaces; under excessive moisture, oxygen is more limited.

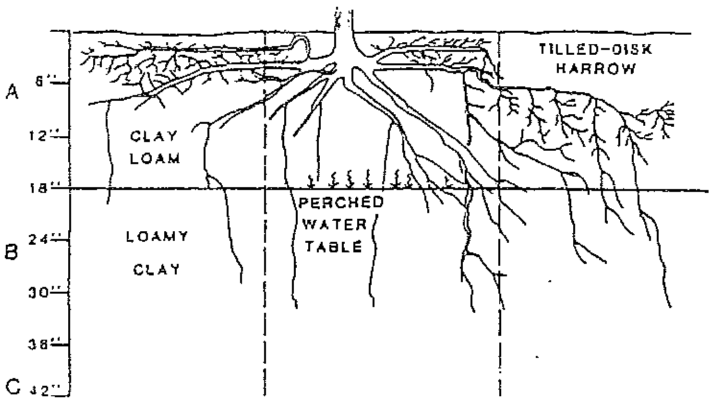
LAYERED SOILS

A common problem among glacial till soils (formed by glacier movement) is where loam is sandwiched between sand. This soil scenario makes a barrier to roots because of the abrupt change from a fine or moderately fine topsoil to coarse subsoil texture. Root and water movement across the abrupt boundary (interface) of the two textures is inhibited. Contrary to most thinking, water will not move quickly from the topsoil (A horizon) into the coarse sand strata or subsoil. Instead, water will temporarily "hang up" (perched) at the interface until several inches of soil above the interface are saturated. Then the water will move across the boundary and into the sand below.



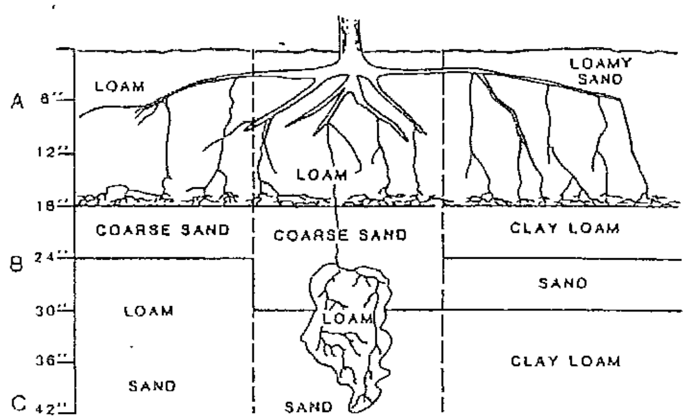
Example of layered soil.

This condition will cause a temporary saturation above the interface and limit much needed oxygen for root growth. A soil profile with this condition has roots proliferating just above an interface.



Fine-textured soil profiles. Left: Clay loam and loamy clay; roots remain in horizon A, sending occasional roots in horizon B. Middle: water cannot move past fragipan; creates a perched water table. Right: root structure where soil is disced.

Crown-rot of fruit trees occurs right above such an interface level—even though sand is below. Most roots won't develop in sandy soils, because of the very low cation exchange capacity (ability to absorb nutrients). Often, however, growers are not aware of this potential problem. The best way to know is to test the soil before planting an orchard. If there is a problem, select a rootstock that best tolerates these conditions and chisel-plow the soil to break up restrictive pans and increase aeration.

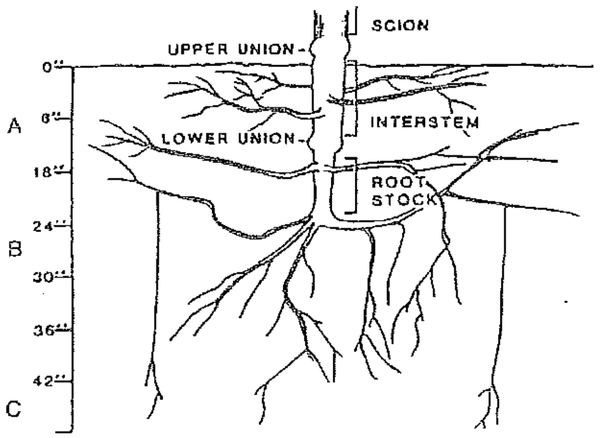


Root structure in three layered soil profiles. Left: roots do not go into coarse sand stata. Middle: roots may tunnel through coarse sand to get to loam soil. Right: roots do not cross clay loam stata.

INTERSTEM TREES

Rootstocks are not the only way to dwarf a tree. Interstems also are a dwarfing mechanism. Horticulturally, the interstem is a good tree: it produces lots of fruit, is precocious, has good light, and is open, but they have a lot of problems. An interstem is a stem from a tree variety that bridges a rootstock with a scion. The most commonly used rootstock-interstem combinations are M9 interstem on an MM106 rootstock and M9 on MM111.

The most common problem with interstems is fireblight. Fireblight can move from the flowers and shoots of a susceptible scion variety through the cortex to the fireblight susceptible interstem, and the tree quickly dies. In this example, you won't necessarily see a strike on the interstem or in the tree until the fall when a canker develops, followed by girdling, and the death of the tree. This problem is most common for fireblight sensitive varieties, such as "Ida Red" and "Rome."



Interstem tree and root development from rootstock and interstem.

Interstems cause rootstocks to sucker more than M7 trees, and the longer the interstem is, the more the tree will sucker. Also the more the interstem is exposed (length) above the ground, the more it will sucker.

Planting depth is crucial to successful interstems. The more interstem above the ground, the greater will be the dwarfing influence, such that with an interstem that is six inches above the ground, the tree will almost be a stunted tree, which is not desirable. An M9 interstem, if planted under the ground, often will root in the soil profile, send out a root system and possibly dominate the established root system even to the point where the rootstock becomes useless. The current thinking is that this is OK, and gives the tree better anchorage, but researchers aren't convinced.

Most growers plant their interstems so that 1/3 of the lower interstem portion is buried. Interstems planted with the lower union at ground level develop some suckering problems.

An orchard is a long-term investment. Therefore, growers should carefully analyze their soil and rootstock needs before planting. Knowing the soil profile, and perhaps correcting any problems, could save the grower in the long run.

Table 9. Sample of pollination model.

Question	Grower Response
Prediction Based on Weather	
Would you like a pollination prediction based on predicted weather and no. of bee colonies?	Yes
Please type the date you would like the pollination prediction for. (The maximum prediction date is 2 days into the future). Please enter date in the form MM/DD/YY.	5/12/81
If you plan on keeping the same no. of honey bee colonies in your orchard during the prediction, type same. If you plan on adding colonies, type add. If you plan on removing colonies, type remove.	Add
How many colonies do you wish to add?	200

Sample Prediction

G.D. Hoffman
Traverse City

***W A R N I N G: These pollination levels are predictions--they are not actual occurrences.

These predictions were made using weather predictions 5/11/81 to 5/12/81 and a total of 200 honey bee colonies.

As of 8:00 pm on May 12, 1981,
based on your orchard design, predicted weather conditions, and no. of honey bee colonies chosen for this prediction, your pollination levels are predicted to be:

Red Delicious	.73% fruit set
McIntosh	.68% fruit set

***N O T E: 7.00% fruit set on your Red Delicious trees indicates a full commercial fruit set has been achieved in your orchard.

Information for Pollination Analysis

What is the total acreage of your orchard?	250 acres
What is the distance between the rows (in feet)?	16 ft
What is the distance between the trees in each row (in feet)?	10 ft
What variety are you using as a pollinizer?	McIntosh
What is the average height of your Red Delicious trees (in feet)?	10 ft
What is the average height of your pollinizer trees (in feet)?	10 ft
What is the average width of your Red Delicious trees?	7 ft
What is the average width of your pollinizer trees?	10 ft
What is the average trunk height (i.e., ground to first flowering branch) on your Red Delicious?	1.5 ft

Table 9. (continued)

Question	Grower Response
What is the average trunk height (i.e., ground to first flowering branch) on your pollinizer?	2.0 ft
What is the average number of flowering spurs per meter of branch on your Red Delicious?	13
What is the average number of flowering spurs per meter of branch on your pollinizer?	25
Have you taken a flower viability count?	Yes
What is the percent viability on your Red Delicious?	85
What is the percent viability on your McIntosh?	80
Try to visualize your orchard in terms of a repeating pattern of Red Delicious apple and apple and pollinizer trees.	
How many rows are in the pattern?	3
How many 100% Red Delicious apple rows are in a block or pattern?	2
Describe the row(s) containing pollinizer trees, i.e., 1/2 means one half of the row contains pollinizer trees, 2/3 means two thirds of the row contains pollinizer trees, 1/1 means the row contains only pollinizers, etc....	1/1
What is the date of the first day of bloom? Please enter date in the form of MM/DD/YY.	5/10/81
Have bees already been placed in your orchard?	No
Do you plan on introducing bees on 5/10/81?	Yes
What time on 5/10/81 do you plan on introducing these bees (military time)?	2100
How many honey bee colonies do you plan to add?	250

Sample Prediction

G.D. Hoffman
Traverse City

As of 8:00 am on May 14, 1981, based on your orchard design, actual weather conditions and no. of honey bee colonies present in your orchard, your pollination levels are:

Red Delicious	1.93% fruit set
McIntosh	1.05% fruit set

***N O T E: 7.00% fruit set on your Red Delicious trees indicates a full commercial fruit set has been achieved in your orchard.

1 9 8 1 P R O J E C T E D Y I E L D F O R Gloria Hoffman, Traverse City:

Red Delicious	249.27 - 332.35 bushels per acre 62316.52 - 83088.69 total bushels
MacIntosh	532.64 - 710.19 bushels per acre ******** - ******** total bushels