

Seedling: A rootstock from apple seeds, with a variable genetic makeup and suckering and disease susceptibility. Varieties on this rootstock produce the largest trees.

Pollination

Pollination is the sexual portion of a tree's life cycle and involves the integration of several biological and physical factors, including cultivar compatibility, synchronous blooming, insects, and proper weather conditions. If any one of these components is missing or limiting, crop yield and quality can be affected.

All apple cultivars require cross-pollination to ensure commercial crops. Varieties differ in their self-fruitfulness. For example, Golden Delicious is considered partially self-fruitful, while Delicious largely is self-unfruitful. Regardless of the degree of self-fruitfulness, provide cross-pollination in every planting.

With respect to cross-pollination, all red sports and spur types are considered the same as the parent variety. For example, Yorking is not a pollinizer for York Imperial. Closely related varieties do not pollinate each other; for example, McIntosh, Early McIntosh, Cortland, and Macoun. Triploid varieties do not pollinate any varieties. Otherwise, all varieties with satisfactory pollen are pollinizers of each other if the bloom periods overlap. It is advisable to have three pollinizer varieties in all Stayman and Winesap blocks.

Cold periods during flowering can reduce pollination and subsequent fruit set. Pollen may fail to germinate when temperatures are below 41°F, and pollen tube growth is extremely slow below 51°F. Therefore, in some situations, temperatures could be warm enough for bees to fly (65°F), but if the weather turns cold the pollen tubes may not grow fast enough before the embryo sac deteriorates.

Effective Pollination Period (EPP)

The Effective Pollination Period (EPP) is the difference between the period of time for pollen tube growth and that of ovule longevity. The longer the effective pollination period, the greater the likelihood of adequate fertilization and seed development. Pollination must occur within 2–4 days after the flowers open; otherwise, the embryo sac will degenerate before fertilization can occur. Studies have shown that this period can vary depending upon cultivar.

The growth of the pollen tube and eventual fertilization of the embryo is largely dependent upon temperature and its relationship to the Effective Pollination Period. The EPP was introduced in the mid-1960s as a way of establishing the time frame between when a flower is pollinated and when the embryo becomes unreceptive. After pollination it takes a certain time for the pollen tube to reach the embryo sac. Once a flower opens, the embryo has only a limited time when it is receptive. If the pollen tube does not reach the embryo before it degenerates, then the flower will not set. The length of the EPP will vary by cultivar, flower position within the cluster, and by certain cultural practices. In general, the EPP can be as short as 3 days and as long as 12 days; Delicious has one of the shortest EPP's.

In 1970, Williams and Wilson developed a temperature response index to allow the estimation of the time required for a pollen tube to grow to the embryo (see below). The index is based

upon the daily mean temperature over a period of days. When the index reaches or exceeds 100 percent, the pollen tube should have reached the embryo and fertilized the egg.

As an example, suppose the average mean temperature over the past five days had been 50°, 54°, 50°, 52°, and 59°. Pollen tube growth would be expected to be 14 + 20 + 14 + 17 + 50 = 115 percent, meaning pollen tube growth would have taken slightly less than 5 days.

Effective Pollination Period Index

Mean daily temp (°F)										
41	43	45	46	48	50	52	54	55	57	59
% Pollen tube growth index										
8	9	10	11	12	14	17	20	25	35	50

Table 1-6 gives a partial listing of the pollen nature of several apple varieties. Your extension pomologist can provide information about the pollination requirements of varieties not listed.

Five conditions are necessary for satisfactory cross-pollination:

- Pollinizer and main variety bloom periods must overlap.
- The pollinizer variety must have viable diploid pollen.
- The pollinizer variety must be located near the producing tree.
- Bees and other insects must be present in the orchard and be active at bloom.
- Weed blossoms, such as dandelions, mustard, and wild radish, should not be present in quantity since they attract bees away from fruit tree blossoms.

Certain varieties have a biennial bearing tendency. During the "off" year of the pollinizer, the adjacent variety, although an annual bearer, will tend to become biennial because of the lack of cross-pollination. This is not as serious when one of the two is relatively self-fruitful; however, the problem must be considered along with all the other factors that affect pollination.

A pollinizer is the source of pollen necessary to set fruit. A pollinizer might be another tree with compatible pollen or a bouquet of flowering branches placed in the orchard; whereas a pollinator transfers pollen from tree to tree. The most important pollinators are bees.

Trees that provide sufficient compatible pollen for the main cultivar(s) in the block are necessary for pollination. A desirable arrangement is a pollinizer located not more than 100 feet from the variety to be pollinated. In larger blocks, plant two rows of pollinizer (starting on the windward side of the block), four rows of main variety, two rows of another pollinizer, four rows of the main variety, then two rows of the first pollinizer, etc., and repeat the arrangement across the block. We recommend that no fewer than three pollen-compatible varieties be planted in an orchard. Thus, for example, if you are planting a Delicious block, select two additional suitable pollinizer varieties to plant.

Where additional pollen is needed, graft a pollinizer branch into each tree. Select main variety and pollinizer trees with overlapping annual bloom times. Large bouquets of pollinizer branches placed in drums of water near main variety trees may be used when no other pollinizers are available. The nearer the

pollinizer to the producing tree, the better distribution by the bees of pollen to all blossoms.

All fruit species require pollination to set fruit. Some species are self-fruitful and do not require more than one cultivar per block. Peaches, nectarines, tart cherries, most apricots, and some European plums are self-fruitful, and a solid block of one cultivar may be planted. Apples, pears, and sweet cherries require mixed plantings of different cultivars for adequate cross-pollination.

Improving conditions for pollination can lead to increased production owing to larger fruit size and/or a greater number of fruit per tree. Research in Massachusetts has shown that fruit size and calcium content are directly related to the number of seeds per fruit, with the number of seeds being dependent on good pollination. The more pollinizer trees in a planting, the better the potential for cross-pollination. However, using pollinizers means the loss of some efficiency in orchard operations. Having two or more cultivars in an orchard may pose problems in spray-to-harvest limitations and cultural practices, and it may confuse pickers, resulting in bins of mixed cultivars. There also may be an inefficient use of land owing to differences in growth habits. These disadvantages, however, are far outweighed by the greater yields associated with pollinizer use.

Pollinizer placement

The placement of pollinizers is important. Ideally, every tree in an orchard should be located as close to a pollinizer tree as possible. However, efficient orchard production practices do not include scattering pollinizers of commercial cultivars throughout a block. (An exception is listed below in the discussion of ornamental crabapples.) The preferred arrangement of pollinizers is in solid rows. One scheme is to alternate two rows of pollinizers between four rows of the major cultivar. An exception is planting cultivars, such as Delicious, that have a tendency to be less fruitful. In these instances, and when it is desirable to maximize pollination, a pollinizer row should be set every third row.

Supplemental pollination practices

Even with an adequate allowance for pollinizers, it may sometimes be necessary to provide for additional pollen when weather conditions do not favor cross-pollination. Using hive inserts with commercially obtained pollen is a common practice that can increase pollen sources. Inserts are specially constructed to fit in the entrance of hives and are filled on a frequent basis with pollen. The inserts are constructed so that bees are forced to track across the pollen and carry it to the flowers as they forage.

A second method of increasing pollen is to cut bouquets of flowering branches from trees elsewhere in the orchard and place them in large containers of water within the tree rows. Bouquets should be checked daily and replenished as needed.

A third method is to graft selected limbs with a compatible pollinizer branch. The disadvantage of this method is the necessity to clearly mark the limb to prevent it from being pruned out in the winter and prevent harvest crews from mixing the fruit in bins. All these methods should be viewed as supplemental means of increasing pollination. The best pollination method is to have an adequate number of pollinizer cultivars and strong, healthy honey bee colonies.

Using ornamental crabapples

Planting annual blooming ornamental crabapple trees to provide additional pollen and improve cross-pollination has been suggested and has been tested by a number of Pennsylvania growers. Ornamental crabapples are noted for their abundant annual production of flowers. Frequently, flowering crabapples will bloom on both spurs and 1-year-old wood. The wide variety of available cultivars allows the grower to achieve enough overlap of bloom that even the latest flowers on the main cultivar have an equal opportunity for cross-pollination.

Trees are propagated on dwarfing rootstocks and placed between the trees of the main cultivars to be pollinated. The trees are pruned so that they do not crowd the commercial cultivar.

Using ornamental crabapples has several advantages. First, it allows the grower to plant a single cultivar block and to manage the block as a single unit. Second, it eliminates the need for less profitable cultivars in a planting solely for their use as pollen sources. Third, it prevents pickers from mixing two similar apple cultivars in harvest bins and reduces the need for multiple harvests in blocks of mixed cultivars.

Some of the more commonly used crabapple cultivars are Manchurian, Pioneer Scarlet, Rosedale, Golden Hornet, Snowdrift, and Simpson 10-35. Nearly every tree fruit nursery sells ornamental crabapples. Growers should exercise caution, however, in selecting a particular crabapple for their orchards. Not all crabapples are suitable for use as pollinizers. Research has shown that white single flowering crabs may be better for cross-pollination because these flowers are most like apple flowers. Crabapples with darker-colored flowers may alter honeybee visitation patterns.

We recommend a minimum of two to three different cultivars with slightly different bloom seasons. How many pollinizers to plant will vary with how difficult it is for the apple cultivar to set fruit. Golden Delicious blocks require fewer pollinizers, whereas Delicious blocks require more trees per block. A common scheme is to plant a crabapple between every third tree in every third row. This situates every tree of the main cultivar adjacent to a pollinizer. Crabapples can also be interplanted in existing blocks that have a traditional pollinizer arrangement. The addition of the crabapples will increase the potential for pollination and help in situations where the fruiting pollinizers may have lost their flowers due to cold injury or become biennial.

Bees and pollination

Honey bees are our most important managed pollinators. Their activity assures sufficient cross-pollination, without which small or misshapen fruits and low yields may result. Although many species of bees can be found in an orchard during bloom, most of these species vary in their abundance from year to year. In addition, regular pesticide applications may limit the number and variety of these pollinators (see Table 1-9), and some agricultural practices destroy their natural nesting sites. Honey bees can be managed, however, to provide consistent pollinator abundance from year to year.

The changing pollination picture

With the introduction of parasitic honey bee mites, the pollination picture is changing rapidly. Abundant feral colonies (wild colonies nesting in trees or other cavities) once provided a measure

of pollination security for fruit and vegetable growers; however, this is no longer the case. Feral honey bee colonies are now nearly nonexistent in most areas. Estimates vary, but the Northeast may have lost 80 percent of its feral honey bees.

Despite intense efforts to protect their bees, beekeepers are losing large numbers of colonies to these mites and the diseases they transmit. As a result, fewer beekeepers are providing honey bee colonies for growers. In addition, the quality of honey bee colonies, at times, may be marginal for the purpose of pollination. Never before has the pollination situation been so critical. To ensure maximum crop yields, growers now must give careful attention and consideration to crop pollination.

To ensure adequate quality and numbers of colonies, growers should consider the following:

- Contact beekeepers early. Since honey bee colonies may be in short supply during some years, it is critical to contact beekeepers as early as possible so they know you are depending on them to supply bees. If you do not have a past relationship with the beekeeper, you should make initial contact with him or her in the fall. Beekeepers assess the survival and strength of their colonies from mid-February to mid-March. Contact your beekeeper during this time to be certain that enough bees are available for spring pollination. In addition, you should make every effort to give beekeepers at least 48 hours' notice to move bees onto the crop.
- Draw up a pollination contract. To prevent misunderstandings, it is a good idea to draw up a pollination agreement between the grower and the beekeeper. This will ensure that enough pollinators are provided and that beekeepers are protected from pest control practices that may injure bees (Figure 1-5).
- Obtain an adequate number of colonies. The number of honey bee colonies you will need will vary depending on the crop, location, attractiveness of the crop, density of the flowers, length of the blooming period, colony strength, and competitive plants in the area. The rule of thumb is to start with one colony per acre and make adjustments from there. Areas well populated with wild solitary bees and wild honey bee colonies will not need as many rented colonies.
- Obtain bees at the appropriate time. For apples and other tree fruit, move colonies in at 10 to 25 percent bloom. If primary blossoms produce the choice fruit, however, bees should be present at the start of bloom or when king bloom on the south side of trees starts to open. Competing bloom from other flowers in the orchard, such as dandelions, should be eliminated by mowing, cultivation, or the use of herbicides. For melons, cucumbers, squash, strawberries, blueberries, and cranberries, honey bees should be moved onto the crop when the crop is attractive to the bees. This means that there should be many blooming flowers (10 to 20 percent) to attract bees to the crop.
- Place colonies for maximum effect. Place colonies in groups of four to eight in favorable locations throughout the orchard or field to provide even distribution of the bees. In large orchards or fields, pollination is just as effective if groups of 10 to 20 hives are strategically distributed in sunny, wind-protected spots. Colonies should be protected from the wind

and exposed to the sun from early morning until evening. Bales of straw or packing boxes stacked behind colonies offer wind protection. Colony entrances that face east or southeast encourage bee flight. Hives should be placed off the ground, and front entrances should be kept free of grass and weeds. Do not place colonies under trees or in the shade.

Bee activity is determined by weather and by conditions within the hive. Bees rarely fly when the exterior temperature is below 55°F. Wind speeds above 15 mph seriously slow activity, and activity stops when winds are between 21 and 25 mph. The stronger the colony, the lower the temperature at which bees initiate flight. Cold, rainy weather inhibits foraging. Under marginal weather conditions, foraging is limited to trees close to the hives. An extended period of inclement weather may require greater hive distribution to obtain adequate coverage.

- Assess colony strength: be sure you are getting strong colonies. It is important that the colonies you rent are healthy and contain a large enough population to do the job. For pollination, package bees (bees purchased through the mail and recently installed) and small hives are inferior to strong, overwintered colonies. The field bee population generally is correlated with the amount of brood in the hive. In packages and weak colonies, most of the hive population must remain in the hive to maintain temperatures of 93 to 95°F and rear brood. Two weak colonies are not equal to one strong colony! Colony strength can be assessed in several ways.

1. Inspect hives. This method is the most time-consuming, but also the most accurate for assessing the quality of your investment in rented honey bee colonies. Colonies used for spring-time pollination should have the following at minimum:

- a laying queen,
- one and one-half or two stories (hive bodies or boxes),
- four to six frames of brood, and
- enough adult bees to cover six to eight frames.

These are minimum requirements; stronger colonies with larger populations make superior pollination units and may command a higher price. As these stronger colonies are opened, bees will “boil out” or cover the tops of the frames. When smoked, however, the bees move down onto the frames and may not cover the frame tops. In this case, the frames themselves should be covered with bees. Note that there will be some variability in the quality of the colonies you rent. As a general rule, a group of colonies with 10 percent falling below the minimum standard is acceptable if 10 percent are above the minimum standard. Also, for a variety of reasons, some colonies may become queenless for a time; however, if these colonies meet all the other minimum requirements they still will be effective pollination units.

The Pennsylvania Department of Agriculture Apiary Inspection Service runs a hive evaluation program for colonies used in pollination situations. Inspections are performed by request only. Requests may be made by either the grower or the beekeeper and should be arranged through the state apiarist at the PDA Bureau of Plant Industry, 2301 North Cameron Street, Harrisburg, PA 17110; telephone 717-772-5225. Requests for inspections should be made as early as possible to facilitate scheduling. If an evaluation is requested

POLLINATION AGREEMENT

This agreement is made _____, 20____, between _____, and _____.
(date) (grower's name) (beekeeper's name)

I. TERM OF AGREEMENT

The term of this agreement shall be for the 19_____ growing season.

2. RESPONSIBILITIES OF THE BEEKEEPER

a. The beekeeper shall supply the grower with _____ hives (colonies) of honeybees to be delivered to the _____ as follows:
(orchard, field, etc.)

(Fill in the appropriate line or lines and cross out those that do not apply)

Approximate date of introduction: _____. Number of days after written notice from the grower: _____.

Time in relation to the following amount of bloom:

Description of location(s): _____

(For additional space attach a separate sheet dated and signed by both parties)

The beekeeper shall locate said bees in accordance with directions of the grower, or, if none are given, according to his/her judgment in providing the maximum pollination coverage.

b. The beekeeper agrees to provide colonies of the following minimum standards:

Disease-free colonies with a laying queen as evidenced by brood.

_____ frames with brood, with adult bees to cover.

_____ pounds of honey stores or other food.

_____ story hives.

The beekeeper agrees to open and demonstrate the strength of colonies randomly as selected by the grower.

c. The beekeeper agrees to maintain the bees in proper pollinating condition by judicious inspection and supering or honey removal as needed.

d. The beekeeper agrees to leave the bees on the crop until:

(Fill in the appropriate line or lines and cross out those that do not apply)

Approximate date of removal: _____. Number of days of written notice from grower: _____.

Time in relation to amount of crop bloom: _____

Other: _____

Figure 1-5. Pollination agreement.

(Please complete reverse side)

3. RESPONSIBILITIES OF THE GROWER

- a. The grower agrees to provide a suitable place to locate the hives. The site must be accessible to a truck and other vehicles used in handling and servicing the colonies. The grower shall allow the beekeeper entry on the premises whenever necessary to service the bees, and the grower assumes full responsibility for all loss and damage to his fields or crops resulting from the use of trucks or other vehicles in handling and servicing such colonies of honeybees.
- b. The grower agrees not to apply pesticides toxic to bees to the crop while the bees are being used as pollinators nor immediately prior to their movement if the residue would endanger the colonies. See Beekeeping Topics No. 4 "Honey Bees and Pesticides" for determining which pesticides are hazardous to bees.
- c. The following pesticides, other agricultural chemicals, and methods of application are mutually agreed to be suitable while the bees are on the crop.

- d. The grower also agrees to properly dispose of all pesticide solutions in such a manner that bees will not be able to contact the material while searching for a water source.
- e. The grower agrees to give the beekeeper a 48-hour notice if hazardous materials not listed need to be applied. The cost of moving the bees away from and back to the crop to prevent damage from highly toxic materials shall be borne by the grower.
- f. The grower agrees to pay for _____ colonies of bees at the rate of \$_____ per colony. Payment shall be made to the beekeeper as follows: \$_____ per colony on delivery and the balance on or before _____ of said year.
(date)
Additional moves or settings shall require \$_____ per hive per move.
- g. The grower agrees to provide adequate watering facilities for the bees if none are available within one-half mile of each colony used in pollinating the crop.

Signed: _____
Grower
Beekeeper

Address: _____

Phone: _____

by the grower, the beekeeper will be informed that a request has been made.

Inspections are performed by the local or state apiarist. Colonies are inspected objectively to determine the colony size (number of supers), the presence of a laying queen, the number of frames of brood and adult bees, and the presence of disease and parasites. At least 10 percent of the colonies in an apiary, or a minimum of five colonies, are selected at random for inspection. Inspected colonies are identified by sticker. If selected colonies are banded or stapled, these are not refastened by the inspector. A copy of the evaluation report is given to both the grower and the beekeeper.

2. Assess traffic at hive entrance. This method is less time-consuming but also less accurate. On a warm (70 to 80°F), calm day between 11 A.M. and 3 P.M., bee traffic at hive entrances should be heavy. During a one-minute observation period, strong colonies should have 50 to 100 or more bees arriving and leaving the hive. Bees also should be seen arriving with pollen pellets on their back legs. In weak colonies, perhaps only 10 to 20 bees will be seen arriving and leaving. Colonies that are being used for summer pollination should have even heavier traffic at the hive entrance.

Another crude way to assess colony strength is to observe entrances when temperatures are cool (between 55 and 60°F). The stronger the colony, the lower the temperature at which bees will fly. In general, weaker colonies rarely fly when temperatures are below 60°F. Strong colonies will fly when temperatures are between 55 and 60°F. In general, honey bees rarely fly when temperatures are below 55°F.

3. Assess bee density on the crop. This method allows you to assess the contribution of wild pollinators (honey bees only) in addition to rented bees. If you are using rented colonies, however, this method tells you little about the quality of the bees you have rented. We suggest that if you use this technique and find that the number of bees on the crop is low, you then use options (1) or (2) to assess the strength of the rented bees before renting additional bees.

For apple trees, make observations in late morning during king bloom; at a glance you should see one to two bees foraging on blooms. Make several assessments at different locations around the orchard. Note: This guideline is appropriate only for honey bees and is not accurate for bumblebees or solitary bees. It is only a rough guideline and may change depending on variety and planting conditions.

- Carefully consider the use of bee attractants. Research on sugar-based attractant sprays for improving pollination indicates that such materials are generally ineffective. The entire tree is sprayed with the attractant and bees collect the sugar off the leaves, usually without visiting the flowers. Although this brings more bees into the field or orchard, more pollination does not necessarily occur. In addition, the sugar may be detrimental if it serves as a medium for the growth of sooty molds. Other attractants containing bee-derived communication pheromones, such as geraniol, have proven more successful, but further testing is needed before a full recommendation can be made.

One of the newest and most promising attractants, Fruit Boost®, contains honey bee queen mandibular pheromone.

Canadian research has shown that when it is sprayed on flowering crops, queen mandibular pheromone can result in dramatic increases in yields for some crops. This product is sold in both Canada and the United States, and is being marketed mainly for use on pears, highbush blueberries, Gala apples, and in vegetable seed production. U.S. distributors are located in the Pacific Northwest. For more information, contact Phero Tech, Inc., 7572 Progress Way, RR 5, Delta, British Columbia, Canada V4G 1E9; phone: 604-940-9944; fax: 604-940-9433.

- Other precautions and requirements. Beekeepers should be given at least 48 hours' notice to move bees onto or off the crop. Insecticides applied on or near the crop before or during bloom are a serious threat to bees. Give the beekeeper 48 hours' advance notice of any applications so that the bees can be removed from the field or orchard.

Honey bees need water for temperature regulation and brood production. Provide a clean water supply near the hives. Keep orchard wheel ruts and areas around the pesticide sprayer fillpoint drained to eliminate a possible insecticide-laden water source.

Additional information

The publications listed below are available at your county extension office or by contacting the Penn State Department of Entomology at 814-865-1896, or on the MAAREC Web site at <http://MAAREC.cas.psu.edu>.

- *Beekeeping Basics*
- *Beekeeping Topics: Sources of Bees for Pollination in Pennsylvania, Bees and Insecticides, Pollination Contracts, Basic Biology and Management of the Japanese Hornfaced Bee.*

Sources of pollination rentals

Growers who need bees should make contracts with the beekeepers as early as possible (mid-February) so that proper preparations can be made. Specialized management is necessary in order to develop strong, efficient colonies, especially for early spring pollination. Therefore, beekeepers need to know how many colonies are needed and the approximate time of delivery as early as possible.

For an up-to-date list of beekeepers with colonies of bees for rent (*Sources of Bees for Pollination in Pennsylvania*), please visit the MAAREC Web site at <http://MAAREC.cas.psu.edu/> or contact your county extension office or the Penn State Department of Entomology at 814-865-1896.

Alternative pollinators

Growers of bee-pollinated crops, particularly apples, are becoming increasingly interested in the possible use of solitary bees as managed pollinators. Two species in the genus *Osmia* (mason bees) are currently being used, on a limited basis, for tree fruit pollination: the blue orchard mason bee (*Osmia lignaria*), our native mason bee, and the hornfaced bee (*Osmia cornifrons*), a mason bee that has been introduced from Japan.

Unlike honey bees, mason bees are solitary, meaning all females mate, reproduce, and provision their own nests. Although these bees are solitary, they are gregarious and prefer to nest in groups. Under natural conditions, these bees nest in hollow reeds

or stems of plants, but they can be easily encouraged to nest in cardboard tubes or wooden nesting blocks drilled with holes of the correct diameter.

In the Mid-Atlantic-region, *Osmia* are active only for about 6 to 8 weeks from about mid-April through mid-June. Males emerge about 1 week before pear trees bloom in the spring. Females emerge 2–3 days after males, or longer, depending upon weather conditions. Mating occurs immediately after females emerge.

Both male and female bees make floral visits. Females collect primarily pollen and carry it on the lower surface of their abdomens (unlike honey bees, which carry pollen on their legs). After their ovaries have developed fully, females begin provisioning cells and laying eggs within the nest “tube.” They collect a large mass of pollen first and then nectar, which they regurgitate on the pollen ball. This sticky nectar acts as glue to hold the egg on the pollen ball. After the egg is laid, a mud wall is built and the next cell is provisioned and the next egg is laid. Females can make 1–2 cells a day under favorable conditions.

Newly laid eggs take approximately 3 days to hatch. The larvae consume the pollen over a 2–3 week period. They later pupate and develop into adults, but will remain within their cells throughout winter and emerge the following spring about 1 week before pear bloom.

Management of *Osmia*

Once they are initially obtained, *Osmia* species are relatively easy to manage. They will nest in cardboard tubes or wood blocks that have 5/16-inch diameter openings and are between 4 and 10 inches deep. Under favorable conditions, and with availability of abundant nest sites, populations tend to double or triple from year to year. Females tend to nest in the same area (instead of flying off to seek a new nesting site) when there are 3 to 5 times as many empty as full tubes. Both species of *Osmia* are susceptible to parasitic wasps if they are left in the field during June and July. It is best to remove the nesting tubes from the field once the adult bees are no longer active and store them in an unheated, parasite-proof shelter.

The Japanese hornfaced bee is less cold-tolerant and must be sheltered when temperatures get below 10°F. They do best in a humid, temperate climate, in USDA Plant Hardiness Zones 5–8. You may place hornfaced bees in a refrigerator for winter storage, but make sure humidity levels stay around 75 percent. Hornfaced bees require a cold period before they can emerge from their cells. It should be noted that experience has shown that *Osmia* obtained from the western U.S. may not adjust well to conditions in the Mid-Atlantic region.

While the Japanese hornfaced bee does not occur naturally in our area, the blue orchard mason bee (*Osmia lignaria*) and other solitary bees are common throughout the Mid-Atlantic region. It may be possible to encourage these bees to form aggregations in your orchard simply by providing nesting sites and restricting the use of pesticides during the short period that these bees are active.

To learn more about the management of solitary bees, where to obtain these bees and/or cardboard nesting tubes, please visit the MAAREC Web site at <http://MAAREC.cas.psu.edu/>, or contact your county extension office or the Penn State Department of Entomology at 814-865-1896.

Planting Depth

Apple rootstocks are usually propagated clonally in stool beds and have been selected because they root well. The roots are induced on aboveground parts of a stem. When apple trees are budded high on rootstocks and planted with a union at the ground, the belowground portion of the rootstock has the ability to form roots.

When the union is planted 2 or more inches aboveground, the exposed portion is unable to form normal roots and may form root initials or burr knots instead. Burr knots are areas of rootstocks where roots try to form but cannot because they are not in a medium conducive to root growth. Rootstocks with burr knots do not enlarge radially in a normal fashion because phloem and xylem cells do not develop all the way around the tree. Several species of tree borers may enter burr-knot areas. Thus, apple rootstocks should be planted with the union at ground level. When mechanical tree planters are used, trees may be set too high. However, trees can be set 1 or 2 inches deeper and manually adjusted to the proper depth. Research suggests that the height of the union also will influence the amount of dwarfing induced by a rootstock. The more of the rootstock shank that is exposed the greater the dwarfing. A general rule of thumb is that for every 4 inches of exposed rootstock shank below the graft union you can expect 10 percent more dwarfing.

Fertilizing Newly Planted Apple Trees

Newly planted apple trees require special attention where nitrogenous fertilizers are concerned. Lack of application, improper placement, or high rates can seriously damage young trees. Incorporating fertilizer into the hole at planting is not recommended because this practice can kill trees by burning young roots. Failure to apply nitrogen after planting can result in less-than-ideal growth. The rule of thumb when fertilizing new trees is to apply 0.02 pound of actual nitrogen per year in the orchard for the first 3 years. After this period, nitrogen application should be based on leaf analysis results and shoot growth. Any phosphorus or potassium as recommended by a soil test should have been applied to the field before planting and incorporated.

Follow the suggestions below for newly planted apple trees:

- Apply all fertilizer on undisturbed soil and keep the material 12 inches away from any disturbed soil (for trees planted by either auger or tree planter).
- If the nitrogen source is not critical, use whatever material is cheapest per unit of nitrogen. Table 1-10 lists the amounts of various nitrogen sources to be applied per tree to achieve the required 0.04 pound of actual nitrogen per year. If you use a source other than those listed, calculate the amount of material needed in the following fashion. First, multiply 0.02 by 1 (for a result in pounds per tree); or by 16 (for ounces per tree); or by 454 (for grams per tree). Divide the result by the decimal equivalent of the percentage of nitrogen in the material.

Example: You have a material with a nitrogen content of 46 percent. You wish to find out how many ounces to apply per tree before the beginning of the second growing season.

$$0.02 \times 16 \text{ oz} = 0.32 \text{ oz}$$

$$0.32 \text{ oz} / 0.46 = 0.7 \text{ oz}$$

$$0.7 \text{ oz} \times 2 \text{ years} = 1.4 \text{ oz per tree at the beginning of the second year}$$