▸ Types of raspberries :

Raspberry fruits can be red, black, purple, or yellow. Most commercial raspberries grown in the Pacific Northwest are red fruited. Red raspberries belong to the rose family (Rosaceae). This family includes other fruit crops such as apples, plums, peaches, black raspberries, blackberries, and strawberries. According to bramble expert D.L. Jennings, “Red raspberries are widely distributed in all temperate regions of Europe, Asia, and North America.”

While the taxonomy is rather complicated, European red raspberry forms generally are referred to as Rubusiclaeusand North American forms as R. strigosus. Both are diploid, intercross readily to produce fertile hybrids, and generally are considered subspecies of R. iclaeusL. Other diploid and tetraploid red-fruited raspberry species and subspecies also exist.

While R. idaeusand R. strigosustypes interbreed freely, they exhibit distinctive differences. Rubusidaeusberries have glandless inflorescences and thimble- or conic-shape fruits.

Rubusstrigosusinflorescences have glands and develop into round berries. The canes of North American red raspberries are thinner, more erect, and better adapted to the harsher climate on this continent than are European red raspberries.

Fruit breeders made significant improvements in raspberry cultivars by crossing North American and European types, producing large, attractive, highquality fruits on stout, cold-hardy canes.

Black raspberry cultivars are domesticated forms of Rubusoccidentalis, a diploid species native only to North America.

Although widely distributed in the United States and southern Canada, this species is less cold hardy than native red raspberries and can be found in more southerly locations.

Purple cultivars are hybrids between black and red raspberries.

Black and purple raspberries are grown somewhat differently than red raspberries and are not discussed in this guide.

Raspberry fruits also may be yellow. Yellow raspberries are the same species as red raspberries, differing only in fruit color.

▸ Red raspberry production systems :

Cultural practices described in thisguide apply to yellow cultivars.

There are two types of cultivated red raspberries—summer-bearers and primocane-fruiters.

On summer-bearing raspberries, first-year canes (primocanes) generally are vegetative. In the second year, fruit is borne in early summer on the entire length of the canes (now called floricanes) .

The crop normally is harvested annually. Summer-bearing raspberries can be produced in an alternate-year cropping system, however, by removing all canes during the dormant season every other year.

This strategy creates alternatecropping and noncropping years.

Growers generally prefer to alternate large blocks rather than individual rows.

Doing so greatly simplifies plantation management.

Mowing the canes every other year saves labor costs associated with pruning and training.

Additionally, material and labor costs for noncropping fields are less than for fields of fruit-bearing canes .

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In trials at Washington State University's Vancouver station, 'Willamette' and 'Meeker' were tested in alternate-year cropping for 6 years (three alternateyear cycles). Primocane suppression was carried out each year to help ensure maximum sustained yields. Compared with every-year cropping, however, yields were reduced by 60 percent over the 6-year period. The large yield reductions in alternate-year production generally make this practice uneconomical.

During periods of low berry prices, however, the reduced costs associated with alternateyear production may make it feasible for some growers. Primocane-fruiting raspberries (also known as fall-bearers, everbearers, orprimocane-bearers) produce relativelylarge crops at the tips of the primocanes in late summer and fall. The following summer, they also produce a crop on the lower sections of the floricanes from June through July, at the same time as summerbearing cultivars. Cropping twice each year may reduc fall yields due to competition between th floricanes and primocanes.

Some growers prune all canes to the ground in early spring

and produce only a primocane crop. Some people believe that the quality of summer crop on primocane-bearing cultivars is inferior to that produced on summer-bearing cultivars. It also can be difficult to harvest because the newly developing primocanes obscure the fruiting laterals.

The latter disadvantage is more pronounced in western Oregon and Washington, where primocane growth begins earlier than in cooler locations. Interference with floricane harvest by primocanes is more pronounced in primocane-fruiting than summer-bearing raspberries. This problem is due to the fact that the tops of the bearing canes in primocane-fruiting cultivars are cut off during the first autumn.

The resulting floricanes are relatively short and are concealed by the developing primocanes.
Managing for a single crop per year on primocane-fruiting raspberries reduces pruning labor and other management costs, facilitates harvest, and helps ensure high-quality fall fruits. These advantages, of course, come at the cost of reduced yields, compared to producing and harvesting both summer and fall crops. In greenhouse production or in regions with mild climates, fruiting of primocanefruitingcultivars can be delayed by summertipping of the primocanes to produce off-season crops from late fall through late winter.

Greenhouses and hoophouses covered with plastic film also are used to grow raspberries in regions where the climate does not favor raspberry production.
Hoophouse and greenhouse production is not discussed in this publication.

Raspberries live for many years.Although the canes are bien-

▸ The Red Raspberry Plant :

nial and live for only 2 years, the roots are perennial. Canes form and elongate only during their first year, when they are called primocanes. In their second growing season, canes are called floricanes. Floricanes do not elongate, but develop lateral fruiting shoots. Except for the planting year, or when floricanes are pruned out in some fall-bearing production systems, both primocanes and floricanes are present simultaneously in a planting. A typical red raspberry plant is shown in Figure 1. Red raspberry plantings generally have a commercially productive life of less than 10 years to as long as 20 years in western Oregon and Washington, depending on location. Rotations of 8 to 10 years are common in harsher climates east of the Cascade Mountains or where certain viruses are present.

Root :

Raspberries have an extensive root system consisting of many fibrous, smalldiameter roots. Roots have been found to depths of 6 feet in well-drained soils, but 70 percent of the roots generally are in the upper foot of soil, with 20 percent lying 1 to 2 feet deep. In related studies, 64 percent of the water used by red raspberries wasfound in the top 2 feet of soil.

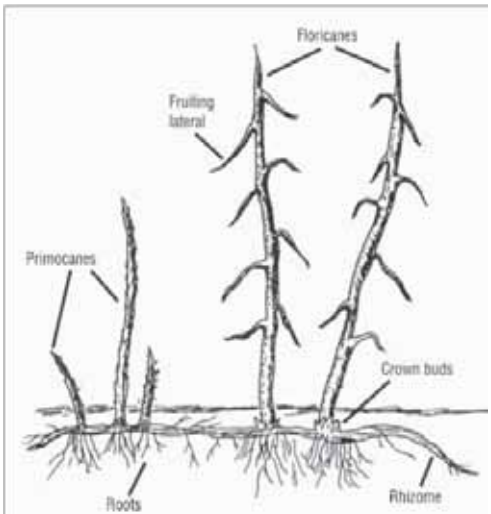

Figure 1. A raspberry plant during early summer showing newly formed primocanes and floricanes formed during the preceding growing season. The leaves and fruits have been removed to show the canes and fruiting laterals more clearly.

Roots start growing in the spring after bud break. If water is adequate, most root growth occurs in midsummer, but growth

continues into the fall after top growth has stopped. Roots produce shoot buds at random locations. These shoots grow to the surface and become primocanes.

Primocane growth and development :

Primocanes are produced from buds atthe floricane base in a section called the crown (the perennial base of the plant) orfrom buds on roots.

Primocanes produced from the roots are known as suckers and usually are less vigorous than those produced from the crown.

Primocane growth or “emergence”starts in the spring, usually in early April in western Oregon and Washington and as late as mid-May in eastern regions of the Pacific Northwest. Primocanes grow rapidly from spring until the hotter days of summer.

They continue to grow in heightmore slowly until cold fall weather limitstheir development.

Primocanes produce leaves and axillary buds at slight swellings called nodes. Red raspberries generally have clusters of one to three buds at each node.

The internode length (distance between nodes) depends on the cultivar, light exposure, and nutrition. Internodes are longer in shady conditions than in full sun, and high levels of nitrogen can increase internode length. Internode length also tends to vary along the length of the cane, with nodes being closer together at the tips of the canes.

Summer-bearing raspberries :

Canes on these cultivars grow 6 to 13 feet tall, depending on the cultivar, production practices, and environmental conditions. Primocanes generally are vegetative the first year and bear fruit the second year on the entire length of the floricane.

Flower bud initiation (flower formation for next year's crop) occurs in late summer as the days grow shorter and temperatures become cooler. This process starts at the tip of the primocane and progresses to the base of the cane. The buds at the very base of the cane and those just under the soil do not initiate flower buds and serve as a source of new primocanes the following spring.

Primocanes seldom branch unless the apical bud is damaged. During long, hot summers and autumns, the buds at the tips of some cultivars break and produce fruiting laterals in the fall. The cultivar 'Willamette' is more prone to primocane tip fruiting than 'Meeker,' for example. This crop is always small and is not harvested commercially. If the tip portion of the primocane fruits in the fall, this section of the cane will die and will not produce fruit the following summer.

Primocane-fruiting raspberries :

Primocane-fruiting raspberries generally produce shorter canes than summerbearing cultivars, averaging about 4 to 6 feet in height. Fruiting laterals also are shorter than those of summer bearers. Flower bud initiation begins at the tip of the primocane in late spring to early summer and progresses downward. Unlike summer-bearing cultivars, however, flower bud initiation does not depend on day length and temperature,

but rather on the physiological age of the cane.

Research with 'Heritage' has shown that flower bud initiation begins when canes have produced about 50 nodes and then proceeds down the canes for about 10 to 12 nodes. The number of nodes that form fruiting laterals during the first season depends on the cultivar.

In western Oregon and Washington, flowers on primocanes generally open in July, and the fruiting season runs from late July through October, depending on the cultivar. In and east of the Cascades, flowers typically begin opening in August or September, with harvest from late August until October. Weather can have a major impact on fruiting season as it affects primocane growth and flowering time. Those portions of the primocanes that develop fruit die by the following spring. Buds farther down the primocanes continue to develop into the fall and againduring the following spring, and they produce a second crop of fruit on laterals in early summer.

The basal buds remain vegetative and are a source for new primocane growth in the spring.

Dormancy and cold hardiness :

In autumn, leaves turn yellow or yellowish- red, dry up, and fall from the primocanes. Before the leaves fall, some nutrients and biochemicals move from the leaves to the canes and roots, where they are stored for next year's growth. The primocane stems and buds remain alive and enter a condition called dormancy, or rest. Once plants enter dormancy, a certain number of chilling hours, generally considered to accumulate at or below 450F, are required before the plant can resume normal

growth and development.

Because chilling requirements depend greatly on variable environmental conditions, they are hard to predict exactly. Chilling requirements generally range from 800 to about 1,400 hours for cultivars grown in the Pacific Northwest. Extended periods of temperatures between 32 and 450F are ideal for chilling, although chilling is reported to occur in raspberries at 280F. Warm weather during winter can make plants lose some accumulated chilling hours.

Based on observations, 'Meeker' requires more chilling hours than 'Willamette.' Following mild winters, during which the chilling requirement has not quite been satisfied for 'Meeker,' bud break in the spring can be relatively poor. Red raspberries are relatively cold hardy compared to black raspberries and trailing blackberries. Nonetheless, red raspberries can be injured when temperatures of 0 to -10˚F are accompanied by drying winds that desiccate the canes.
Not all tissues within the canes or buds are equally cold hardy. Cane tissues have been found to be 3 to 27˚F more cold hardy than buds, depending on the cultivar, time of year, and environmental factors. Within buds, the tissues at the base of the bud (where it attaches to the stem) are less cold hardy than the tissues within the bud scales. Also, raspberries bear both primary and secondary buds. Primary buds, when undamaged, produce most of the crop and are less cold hardy than secondary buds.

The degree of cold hardiness varies throughout the year. Flowers and actively growing tissues may be killed at around 28˚F. As plant senescence and winter acclimation begin in fall, hardiness slowly increases. Maximum resistance to freezing injury is

found in fully acclimated canes exposed to extended, continuous, nonlethal, subfreezing temperatures. Throughout the Pacific Northwest, maximum cold hardiness is reached from about mid- December to early January.

Cold hardiness in raspberries is quite complicated, however, and relative cold hardiness of different cultivars varies depending on the time of year and weather conditions. Some cultivars acclimate early and deacclimate early, while others acclimate and deacclimate later. In November, for example, 'Meeker' and 'Willamette' are some of the least cold-hardy cultivars, while 'Chilliwack' is much more cold hardy. By February through March, 'Meeker' and 'Willamette' are more cold hardy than 'Chilliwack.' Similar differences in relative cold hardiness as a function of season can be observed with other cultivars. Once chilling requirements have been met, relatively short periods of warm temperatures can decrease the canes' cold hardiness. For example, an unusually warm January can cause canes to deacclimate or lose some of their cold hardiness.

If that warm spell is followed by subfreezing temperatures, the canes can be injured. The seriousness of the injury depends on many factors, including cultivar, when the warm spell occurs, how long it lasts, how high temperatures rise, how rapidly and how low temperatures drop, how long the low temperatures last, and cultural practices, such as weed control and fertilization.

The tips of canes deacclimate more quickly and are more likely to be damaged by cold than tissues farther down the stems. Buds on the upper portions of the canes also break earlier in the spring than those on the basal portions. Arc-cane training (see "Managing primocane tops, can promote earlier bud break

at the tops of the arcs, compared to topped canes, making this section of the canes more prone to cold damage. On the other hand, once chilling requirements have been met, topping canes after a warm spell and before a period of subfreezing temperatures can increase cold injury.

Floricane growth and development :

When growth begins in the spring, the overwintered primocanes become floricanes. Floricanes do not increase in length, but buds break along the canes, producing fruiting laterals. The length of the fruiting laterals and the extent of bud break vary by cultivar.

Research in the Pacific Northwest has shown that 'Meeker' never has 100 percent bud break. Generally, only about 40 to 59 percent of the buds break.

In some cultivars, more than one bud sometimes breaks at a node, producing more than one lateral per node. Fruiting laterals produce leaves and flowers.

The number of flowers on a lateral depends on the cultivar and is influenced by environmental conditions. 'Meeker,' for example, typically produces 9 to 16 flowers per lateral. The inflorescences (flower clusters) at the tips of the laterals develop and open before those nearer the cane. Within an inflorescence, the primary flower at the tip opens first.

The range in flower opening times, coupled with slightly earlier emergence of laterals at the tip of the cane, causes fruits to ripen over about 30 days for most summer-bearing cultivars grown in the Pacific Northwest. In some cultivars, ripening continues for as long as 55 days. Following fruit harvest, flori-

canes start to senesce.As they die (from early August to early September), they export 1 to 2 grams of nitrogen per plant to the crown and roots. This rate equals about 4 to 8 pounds of nitrogen per acre. For this reason, it is best to delay floricane removal until fall, rather than removing canes immediately after harvest, unless earlier removal is desirable for disease management.

Yield :

The number of berries and individual berry weights determine total yield. Factors that influence the number of berries are: (1) the number of fruits per lateral, (2) the number of fruiting laterals per cane, and (3) the number of canes per acre. Berry weight is influenced by the number of drupelets per berry and drupelet size.

Total yield includes all fruits that form on the plant. In practice, many fruits are not harvested due to disease, pest, or physical damage. In addition, some acceptable fruits fall to the ground during harvest .

Number of fruits per lateral :

Many factors interact to determine how many fruits will form per lateral. These factors include the following:

- Location of the lateral on the cane
- Percent fruit set (the number of flowers that develop into fruits)
- Cane diameter—Larger diameter canes produce more fruits per lateral.
- Competition with other fruits and laterals on the same plant for water, nutrients, carbohydrates, and plant growth regula-

tors—Reducing competition through primocane suppression (removing the first flush of primocanes in the spring) and managing the number of canes per foot of row or per hill increases the number of fruits per lateral (see Chapter 5). This effect is especially pronounced at the base of the floricanes.
• Light intensity —Shading by overly dense canopies reduces flower budinitiation on primocanes, reducing the number of flowers per lateral for next year's crop.

Number of fruiting laterals per cane :

Factors that influence the number of fruiting laterals per cane include the following:
• Winter pruning practices—Topping reduces the number of nodes (potential
fruiting laterals) per cane.
• Cane vigor (growth rate) —Vigor influences internode length. If internodes are long, there are fewer nodes or laterals per foot of cane length. Internode length increases in response to shade or high soil nitrogen concentrations.
• Percent bud break—Bud break may be influenced by cane length, cultivar, and limiting factors such as lack of sufficient chilling, winter injury, mechanical damage, or disease.
• The number of laterals per node—Some cultivars produce as many as three laterals per node. Multiple laterals usually produce fewer fruits per lateral, but often more fruits per node, than single laterals .

Number of canes per acre :

The number of canes per acre depends on the following:
• In-row and between-row spacing
• Cultivar—Cultivars differ significantly in vigor, an important point to consider in cultivar selection. Selecting cultivars that are vigorous and productive under your cultural and environ-

mental conditions is an important step in ensuring success.
• Plant age
• Cane vigor—Cane vigor depends on the cultivar and age of the planting. Plantings become more vigorous and cane numbers increase as the plants mature. Full crops normally are attained by the third growing season.
• Pruning system—Some growers reduce the number of canes per foot of row when winter pruning. Primocane suppression also reduces the number of canes per acre.
• Cultural practices—Practices such as irrigation and fertilization affect vigor and cane number.

Number of drupelets per berry :

The number of drupelets per berry is determined by how many ovules are fertilized.

Pollination and subsequent fertilization of the ovules are influenced by weather conditions during bloom, nutrient status, disease, and insect damage. Cold, wet, and rainy weather greatly reduces bee activity, particularly for domestic bees. Besides reducing bee foraging, rain can dilute the stigmatic fluid on the pistils and, thereby, reduce fruit set. Cold temperatures also affect the plant directly.

Even if a flower is pollinated, temperatures below about 60oF slow pollen germination and pollen tube growth. This problem is less common in raspberries, however, than in blueberries, currants, and other fruit crops that bloom in early spring.

Raspberry bushy dwarf virus, which is pollen-borne, reduces the number of drupelets that develop on the berries, thereby causing “crumbly” fruits that do not hold together well.

Drupelet size :

Two berries that have an identical number of drupelets may differ in fruit size or weight. For example, drupelet size is affected by cultivar. Water stress (insufficient irrigation, for example) also can reduce drupelet size and thus berry weight.

Interactions among yield components :

Red raspberries have great capacity to compensate for changes in yield components. If one or more factors are adversely affected, the plant tends to respond in ways that offset the potential yield reduction.

If the number of buds per cane is reduced by topping, for example, the remaining laterals tend to bear more fruits. Topping also can result in a higher percentage of bud break on the remaining nodes. Similarly, removing some floricanes in a hill

▸ Plantation Establishment :

Selecting a site :

Selecting an appropriate site is critical for successful red raspberry production. Fortunately, red raspberries are highly adaptable to a wide range of soils and climates. Nonetheless, factors such as climate, soils, and topography should be considered carefully when choosing a planting site.

Climate :

Red raspberry cultivars are available that are adapted to climates as different as the hot southeastern United States, the cool western Pacific Northwest, and the cold Cascade Mountain and Rocky Mountain ranges. Red raspberries perform best, however, in areas with relatively dry summers, warm days, and cool nights.

Raspberries are temperate-zone plants that require a period of winter dormancy . Depending on the cultivar, approximately 800 to 1,400 hours of exposure to temperatures below 450F are needed to meet chilling requirements. Chilling units do not accumulate as rapidly at subfreezing temperatures or at temperatures much above 450F.

Minimum winter temperatures are also a factor to consider. Cold hardiness is extremely important in and east of the Cascade Mountains, but less so in western Oregon and Washington.
Western Oregon and Washington provide excellent climates for raspberries.

Average minimum winter temperatures range from about 250F

in southwestern Oregon to 100F in northwestern Washington (USDA plant hardiness zones 8-9).

Winter injury can occur, however, following long, warm autumns that interfere with plant acclimation, during unusually cold winters, or where particularly cold-tender cultivars are grown.

Growing seasons in and east of the Cascade Mountains are cooler and shorter than those in the western Pacific Northwest, and winter temperatures are colder. Fruit-growing regions in eastern Oregon and Washington and throughout Idaho experience average minimum winter temperatures from -5 to -30°F (zones 4-6).

Cold temperatures are particularly troublesome when they are accompanied by drying winds.

Summer climatic conditions also play a role in raspberry cultivation. Hot, dry, windy weather during early summer can retard cane growth and cause berries to become soft and seedy. Excessive heat during ripening can cause soft, poorly colored fruit and increase the likelihood of sunscald on the berries. Because of the wide range of climates in the tristate area, cultivar selection is important.

Topography :

Topography is an important consideration in selecting a raspberry site. Gentle slopes with outlets for cold air drainage significantly reduce frost and freezing injuries.

Low-lying frost pockets that trap cold air are poor choices for raspberry production. Good air drainage can also reduce ex-

cessive humidity in the planting, an important factor in reducing fungal and bacterial diseases.

Steep slopes can increase soil erosion and make operation of tractors and other machinery difficult and dangerous. Exposed, windswept sites generally are less suitable for raspberry production than more protected locations.

Soils :

Suitable raspberry soils are deep and well drained with a sandy to loamy texture. Loam and sandy-loam soils 2 to 4 feet deep generally provide the best soil conditions, provided they are well drained.

Sandy or gravelly soils can be suitable for raspberry production, as long as adequate irrigation water is available. Water and nutrient management can be more difficult on such soils. Heavy silt and clay soils and poorly drained soils of any texture create serious challenges in growing raspberries. Wet soils greatly aggravate diseases such as Phytophthora root rot, the most serious root disease in the Pacific Northwest. Avoid these soils for raspberry production.

Also avoid severely eroded soils; they tend to be shallow, low in organic matter, and subject to further erosion. Raspberries tolerate a range of soil acidity, with an ideal soil being slightly acidic (pH between 6.2 and 6.8, with a lower limit around 5.6). Lime can be used to raise soil pH if pH is less than 5.6. Alkaline soils (pH above 7.0) can create micronutrient problems, particularly iron chlorosis. Sulfur can be used to lower pH on alkaline soils, depending on the pH and buffering capacity of the soil. Alkaline soils frequently are associated with alkaline irrigation

water, making pH management particularly challenging.

Other considerations :

Consider previous land use before selecting a raspberry planting site. Tree fruits, strawberries, tomatoes, potatoes, eggplants, peppers, and caneberries can harbor Verticillium wilt, a serious disease in raspberries. A site with a history ofserious Phytophthora root rot problems in caneberries is not likely to be a good choice. Some soil-applied herbicides can remain active for many years.

Also consider surrounding farming activities. Determine whether pesticide spray drift from adjacent farms might interfere with production or with organic certification.

Site preparation :

Site preparation is an important step in developing a successful raspberry farm. Preplant activities often include leveling fields; adjusting soil pH; and installing wells, irrigation main lines, and drainage tiles.

Before planting, identify your soil's characteristics and potential problems. It's best to conduct soil tests at least 1 year before planting. Early testing allows for pH adjustment, which is best done before planting, and for planning fertilization programs. Some materials, such as lime, are best incorporated before planting.

Typical analyses include pH, organic matter, phosphorus (P), potassium (K), sulfates (SO_4), boron (B), and lime requirement. Soil nitrogen analyses for nitrate (NO_3) or ammonium (NHt) may be conducted, but are less useful. Tests for salinity and other macro- and micronutrients are available, if needed. See Chap-

ter 6, “Plant Nutrition Management,” for more information.
Test raspberry field soils for the kinds and numbers of nematodes (microscopic worms) present. Some nematodes transmit serious diseases to raspberries. If plantparasitic nematodes are present, fumigation or other soil treatments, such as soil solarization, may be required before
planting. For more information on nematodes and plant diseases, see Chapter 7, “Raspberry Disease and Nematode Management.” Note that soil solarization has not proven particularly effective in Idaho’s cool climate.

Depending on the previous cropping history, it might be beneficial to produce and incorporate a green manure crop before planting raspberries. When used properly, green manures help maintain soil organic matter and soil structure (tilth). Suggestions for selecting and managing green manure crops are included in Chapter 9, “Organic Production.” A green manure crop may not be needed where raspberries follow hay, legumes, or other soil-improving crops.

Sites that have been planted to sod should be cultivated or rotation cropped for at least 1 year to kill the grasses and create suitable planting beds. Although soil organic matter is important to soil tilth and fertility, raspberries do not require high concentrations for acceptable growth and fruiting. An earlier edition of this guide recommended applying 8 to 12 tons of barnyard manure or 5 to 6 tons of poultry manure per acre before planting raspberries. While such applications can be beneficial, transporting and applying large quantities of manure can be expensive and may be feasible only if fields are located near a livestock operation.

Use soil tests to determine whether large manure applications

will be cost-effective. For barnyard manure, use only materials that have been well composted to reduce the likelihood of importing noxious weeds. Woody materials, including straw, bark, and sawdust, sometimes are incorporated into the soil before planting fruit crops. Soil microorganisms use nitrogen as they break down organic materials. Unless extra nitrogen is applied with uncomposted, woody amendments, soil nitrogen can become temporarily depleted, creating nitrogen deficiencies in crops.

If hardwood sawdust or bark is incorporated into the soil, apply 25 pounds of actual nitrogen for each ton of woody material. For softwood (conifer) or straw materials, apply 12 pounds of nitrogen per ton.

The following year, add about half as much nitrogen as the first year, in addition to the fertilizer needed for the crop. As with manures, purchasing, transporting, and applying bulky soil amendments usually is expensive and may not be costeffective.

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Planting stock :

Use only certified planting stock to reduce the likelihood of introducing nematodes, viruses, root rot organisms, and other

pests into new fields. Using planting stock from your own fields or from neighbors is not advisable because of the risk of introducing pests and diseases.

Although red raspberries are among the easiest fruit crops to propagate, very few commercial growers produce their own planting stock. Propagating high-quality planting stock requires significant investments of time, labor, equipment, land, and structures. Most growers find it more costeffective to purchase raspberry plants from certified nurseries that have the resources and expertise to produce true-to-name, disease- and pest-free stock.

Several kinds of planting stock are available. Dormant plants from the previous season's growth have long been favored by commercial growers. Canes should be at least VA inch in diameter with wellformed root systems. Cane length is unimportant and typically ranges from about 3 to 12 inches. Use care during digging, storage, transport, and planting to ensure that the hair (feeder) roots are not pulled off and that the roots remain moist at all times.

Alternatively, dormant root cuttings from certified nurseries can be used as planting stock. Small, white buds on the root cuttings give rise to new shoots. This method increases the amount of planting material available and produces results similar to those achieved with rooted plants.

Root cuttings generally are !/i6 to 3/(i inch in diameter and of varying lengths. In recent years, commercial production of raspberry planting stock has improved greatly with the development of tissue culture techniques. In this propagation system, small sections of raspberry shoots are surface-sterilized

and placed on a special growth medium in sealed containers. The plants are grown in rooms or chambers where light and temperature are carefully controlled.

The small shoot sections, called explants, produce many new shoots that can be rooted in similar containers or in a soilless growing medium under high humidity in greenhouses. Because each explant produces many new shoots, tissue culture allows a nursery to produce large numbers of plants quickly. More importantly, tissue-cultured plants can be, theoretically, free of viruses and other disease organisms. Unfortunately, newly rooted tissuecultured plants are small, tender, and often survive poorly if transplanted directly to fields. Most growers have better success with plants that have been grown for 1 year in a greenhouse or nursery transplant bed after rooting.

Although more expensive than traditionally grown nursery stock, tissuecultured planting stock can provide greater protection against introducing pests and diseases into fields. Bear in mind, however, that once the tissue-cultured plants are rooted out in nursery greenhouses or fields, they may become infected with pest and disease organisms.

Regardless of the planting materials used, ensure that the nursery providing the materials is certified by the state agriculture department and has a reputation for selling high-quality, disease-free plants. For all types of planting stock, be careful not to allow the plant materials to dry out before, during, or after planting.

Row spacing :

The distance between rows is an important consideration in designing a raspberry planting. Spacing the rows too far apart

reduces yields.

Spacing the rows too closely together, on the other hand, makes maintenance and harvest difficult. Row spacing is a decision that lasts for the life of the planting. Take the time to make the correct choice before planting. In the early 20th century, raspberry rows often were spaced 6 feet apart. This close spacing worked well for horse-drawn equipment, but generally is impractical with tractors, mechanical harvesters, and other modem equipment. Typical spacings today are about 10 to 12 feet apart. Allow plenty of room at the ends of rows to turn equipment around.

Design row spacings based on the equipment that will be used. If a small tractor is used, crop rows are properly narrowed, and canes are supported on trellises, row spacings of 8 feet are possible. Such narrow spacing is not always convenient, however.

Larger tractors and some over-the-row harvesters require wider row spacing. If the field will be mechanically harvested, consult the equipment manufacturer for recommendations on row spacing and training systems.

For mechanically harvested fields, row length is determined by the maximum length of drip irrigation tubing (if used) and the capacity of the harvest equipment. If the crop is to be hand harvested, place cross roads no more than 150 to 200 feet apart to allow workers to move the fruit to roads for pickup.

Hill systems :

Summer-bearing red raspberries can be grown in hill systems on raised beds or flat ground. The canes are trained by tying

them together in bundles, which then require some form of support.

By bundling canes together and arcing them over the trellis wires (Figure 3), growers see increased yields over hedgerow systems, where canes must be topped. This factor is especially important in the long, warm growing region west of the Cascades, where canes grow taller than they do east of the Cascades.

Hills usually are established by setting traditionally propagated or nursery-matured planting stock 2l/2 feet apart in the rows. Canes traditionally have been thinned to limit the number of canes per hill, although some recent research challenges that practice.

Although home and market gardeners sometimes use fence poles to support canes in hill systems, commercial growers utilize various trellis designs.

Planting systems :

Because they produce primocanes from both the crown area and from buds on the roots, red raspberries can be grown in either hedgerows or hill systems. In mature hedgerows, individual plants are not distinguishable. Instead, there is a continuous row of canes (Figure 2B and Plate 1). In hill systems, individual plants are distinguishable. See Figure 2A, Figure 3 (page 26), and Plate 2. In commercial plantings, summerbearing raspberries can be grown in either system.

Hedgerows are common for summer-bearing raspberries in the eastern Pacific Northwest, where most fields are hand harvested. Spacing the floricanes along the row can facilitate hand

picking. In western Oregon and Washington, most commercial summer-bearing raspberry growers use hill systems. Primocane-fruiting red raspberries are always grown in hedgerows.

Hedgerow systems :

Hedgerows are best established by planting rooted plants or root cuttings about 2 feet apart in rows. Primocanefruiting raspberries typically are grown in 12- to 18-inch-wide hedgerows, whereas summer-bearing hedgerows are kept about12 inches wide.

The hedgerow width is maintained through hand pruning, mowing, chemical cane burning, or rototilling along the edges of the rows. Overly dense canopies increase pest and disease problems and can reduce flower bud formation due to shading. Cane density in hedgerows can be managed by removing some primocanes during winter or spring pruning, leaving a desired spacing between adjacent canes. This practice is used only for summer-bearing raspberries. See Chapter 5, "Plantation Maintenance," for more information.
While hedgerows have the advantage of making hand picking easier, they have several disadvantages. Canes in hedgerows are shortened or topped to about 6 feet high since they are too spread out to bundle and tie to the trellis wires. Topping reduces yields, and the shorter canes can slip between the top wires, necessitating tying the canes to the wires and increasing labor costs.

Trellis designs Summer-bearing cultivars :

Commercial summer-bearing red raspberries require trellises for support. Many trellis configurations have been developed,

and it is beyond the scope of this guide to describe all of them. If the crop will be mechanically harvested, consult the harvester manufacturer to determine which trellis system is best for your equipment.

Between the wire tension and weight of the canes and fruit, the stress on the end posts can be very high. Row ends often consist of two cross-braced posts set deeply into the ground, often leaning backwards from the trellis wire. Fastening each end post to a buried concrete anchor provides additional support.

Wire tension is maintained by using ratcheting tensioners located at the ends of the rows. For very long rows, additional tensioners may be required along the rows. Always treat wooden posts to resist rot and use rust-proof, high-tensile, 10- to 12-gauge wire.
The simplest trellis consists of a single wire strung about 5 to 6 feet above ground and supported on wooden or metal posts spaced 25 to 30 feet apart. Two-, three- or four-wire trellis systems are more common in commercial plantings.

In many designs, one wire is run about 12 to 24 inches above the ground to support the drip irrigation line. Keeping the lines above the ground greatly reduces damage to the irrigation tubing during pruning and other operations. Snap fasteners are commercially available to hold the irrigation tubing to the trellis wire.

Upper wires usually are placed 5 to 6 feet above the ground. In some designs for hedgerow training of summer-bearing raspberries, two wires are strung tightly together. Primocanes are trained by pinching them between the two wires. While the idea is to eliminate the need for tying, in practice the canes

tend to slip from between the wires.

A more common design is to fasten two rather loose wires directly to the posts or to short cross arms about 24 inches above the ground. These wires are pulled out and down to capture and hold young canes and then retightened, thereby protecting the canes from damage by workers and equipment. One or two more wires are placed 4/4 to 6 feet above ground, and the canes are tied to these wires (Figure 3). For arc training, bundles of canes can be bent over the top wires and fastened to another wire below (Plate 3).

The designs discussed so far utilize one or two top wires, with all canes trained in a single, narrow row. In another design, cross arms on the support posts hold two to four top wires 1 to 3 feet apart in what is called a divided or V trellis (Plate 4). Theoretically, dividing the canopy increases light exposure and air movement into the canes, thus increasing yield and reducing disease problems. This design can be used with both hedgerow and hilltrained plants.

While the divided canopy system has enjoyed some success in the eastern United States, it has not proven as popular or economically beneficial in the Pacific Northwest. The added cost of constructing and maintaining the trellis, plus the extra labor needed to tie up a divided canopy, makes a V trellis impractical for some growers.

Primocane-fruiting cultivars These cultivars can be grown free standing, but often are supported on a simple trellis to keep the canes from bowing out into the alleys (Figure 4). Because the wires in this case bear little weight, end and in-row support posts can be lighter than for summer-bearing raspberries. Run

one trellis wire along each side of the berry row about 2 to 3 feet above the ground.

Anchor the wires to a post at each end of the row. Every 25 to 30 feet, use a crossbar 12 to 18 inches wide to support the wires and keep them from being pushed outward. The cross-bars can be made of reinforcing bar used for concrete work. Twist the ends of the bar into small loops and string the wires through the loops.

Planting :

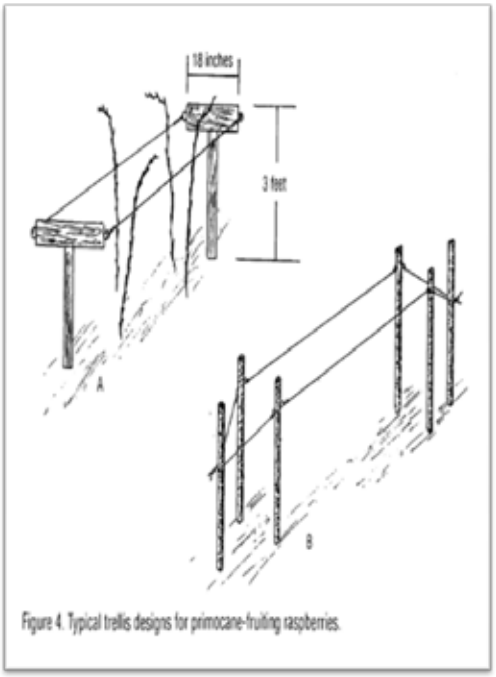

Figure 4. Typical trellis designs for primocane-fruiting raspberries.

Although raspberries are remarkably tough plants, care is needed during planting to ensure survival and rapid establishment.

Order plants well in advance and specify the shipping date. Whether using rooted plants, root cuttings, or tissuecultured plants, keep the shipping and storage times as short as possible.

Most planting stock i shipped while it is dormant and relatively tolerant of low temperatures. Tissue-cultured plants can be shipped when they are actively growing, but they can be damaged by freezing temperatures. High temperatures can damage
any planting stock.

If possible, keep plant materials refrigerated at 32 to 360F until you are ready to plant. Tissue-cultured plants will not be damaged at these temperatures. While in shipment and storage, the roots must be kept moist. Usually this is accomplished by enclosing the roots or entire plant bundles inside plastic bags and storing them in a refrigerator. Moist excelsior, shredded newspaper, sphagnum moss, or other materials sometimes are packed around the roots to retain moisture. When planting, remove from storage only as much stock as can be planted in an hour or so. Keep the roots moist during transport to the field and planting. A common method is to wrap wet burlap bags around the roots.

Setting the plants :

Raspberries can be planted by hand, by machine, or by a combination of the two. If the plants are to be set by hand, V-shape furrows generally are used. The furrows can be made with various tractor-drawn implements, including plows and disks. Using a road, fence, or other object as a guide, create an initial furrow. That furrow serves as a guide for subsequent furrows. Often, a marker stick or similar device is attached to the front of the tractor. By keeping the marker over the previous row, the driver can create uniformly spaced rows. For hedgerows, space plants or cuttings about 24 inches apart. For hill systems, set plants about 30 inches apart.

Marker sticks provide a convenient way to ensure consistent in-row spacing. With rooted plants or root cuttings, spread the roots along the bottom of the furrow and cover with soil. Unless they are visibly damaged, raspberry roots are seldom pruned during hand planting. Tissue-cultured plants also can

be set directly into fields, although they are tender, and survival can be problematic.

Self-propelled or tractor-drawn mechanical transplanters are available for larger plantings. Depending on the design of the transplanter, long roots can create difficulties and may need to be trimmed. Some transplanters simply create a planting furrow. Workers riding on the transplanter set plants by hand into the furrows. Packing wheels on the back of the transplanter firm the soil around the raspberry plants. Planting depth is an important factor in establishing a raspberry plantation. Set tissue-cultured plants just slightly deeper than the plugs. Canes are best planted at the depth at which they were growing in the nursery. Plant root cuttings shallowly and cover with approximately 3/4 inch of
soil. Regardless of the planting method used, always have someone follow the planters to correct any mistakes.

Heavily irrigate the raspberry plants as soon as possible to help settle the soil around the roots, eliminate air pockets, and keep the plants from drying out.

While the plants are establishing, irrigate frequently enough to keep the soil moist. Irrigation is especially important for tissue-cultured plants and root cuttings. Traditionally, authorities have recommended cutting the tops of the floricanes (sometimes called the handle) to 3 to 4 inches above the ground at the time of planting. Ideally, three to five strong primocanes will develop from the plant. These canes will bear fruit the following year.

▸ Plantation Maintenance :

Row management :

Regardless of the planting system, use a mower or cultivator to remove canes emerging in the alleys or outside the desired row. For summer-bearing raspberries, keep rows about 12 inches wide.

For primocane-fruiting raspberries, keep rows 12 to 18 inches wide. When summerbearing raspberries are grown in a hill system, the primocanes that emerge between hills are also removed.

Pruning & trainingmSummer bearing raspberries :

Pruning and training of summer-bearing raspberries includes floricane removal, primocane pruning, optional primocane thinning, and primocane top management. These activities usually are done in fall and winter.

Removing spent floricanes :

The floricanes of summer-bearing raspberries can be removed any time from just after harvest through the following spring. After harvest, floricane leaves turn yellow and eventually fall from the dying canes.

Research has shown that nitrogen, carbohydrates, and other important plant biochemicals move from the dying floricanes into the crown and roots. This recycling of nutrients and plant compounds provides perennial plants great survival and growth advantages. Movement of these chemicals, however, requires time; thus, most experts recommend delaying flori-

cane removal until late fall. In western Oregon and Washington, the spent floricanes typically are removed just before training the primocanes
in the fall. However, if diseases, such as yellow rust, are creating serious problems, remove the floricanes as soon as possible after harvest. Some growers also choose to remove spent floricanes immediately after harvest due to labor considerations.

Pruning primocanes :

Primocane productivity depends on cane diameter and internode length. In both the hedgerow and hill systems, pruning primocanes involves removing canes that are damaged, very thin (pencil width or smaller), too short to train, or outside the hill or row. Primocane pruning can take place anytime during the dormant season.

On colder sites in and east of the Cascade Mountains, primocane pruning often is delayed until late winter or early spring (before growth starts), so that the grower can identify and remove winterdamaged canes.

Thinning primocanes :

Some growers also manage cane density in hills by thinning primocanes. However, research has shown that increasing the number of primocanes per hill increases yields. In an Oregon study, for example, the greatest yields were obtained with 15 canes per hill when compared to 5- or 10-cane systems. Similar results have been reported in Washington and Idaho, with densities of up to 20 canes per hill proving productive. Although the number of canes per hill can impact canopy den-

sity and, therefore, susceptibility to diseases, canopy density can be more easily managed through training practices (see "Managing primocane tops," below).

For hedgerow-trained summer-bearing red raspberries, thinning the primocanes to leave four to six strong canes per linealfoot of row is a common practice.

Managing primocane tops :

Pacific Northwest growers use three methods for managing primocane tops. In the first method, primocanes are topped to 6 feet in length or 6 inches above the top wire. Topping was long a standard technique for hill-trained berries and continues to be common with hedgerow-trained summer-bearing raspberries, although it reduces yields. Leaving the canes as long as can be conveniently harvested generally increases yields.

Topping primocanes before a cold spell can increase the risk of cold injury to the cane wood and buds, particularly in mild-western Oregon and Washington areas.

Growers commonly top the primocanes after the bundles have been tied to the trellis and the risk of temperatures below 50F has passed. Topping usually is done in February in the western Pacific Northwest; it may be delayed until March or April on cooler eastern Pacific Northwest sites. In the second method, the primocanes are not shortened. Instead, they are bent over the top trellis wire to form an arc In a practice referred to as arc training (Plate 3). In fields that are machine harvested, the canes should be arced in the direction of machine travel down the row to avoid cane breakage during harvest. The third technique combines topping and arc training. In this method, a small por-

tion of the primocane tip is removed.
The amount removed depends on cane vigor. The primocanes are then bundled and arc trained. In Oregon trials, keeping the entire cane length (averaging about 9 feet) during training increased yields by 20 to 25 percent compared with shortening canes to 6 feet. Average berry size, however, decreased by about 10 percent.

It seems that fruiting laterals at the tips of untopped canes are short and produce relatively small fruit, thereby decreasing the average berry weight for the hill. For fresh market production, keeping the entire cane length might be a disadvantage because of the potential for reduced fruit size.

Shortening the primocanes provides less of a disadvantage for fruit destined for processing markets, where small changes in fruit size are less important. Slightly topping the canes before arc training reduces yields slightly compared to keeping full-length canes, but has less impact on average berry weight. Summer-bearing red raspberry primocanes are not shortened during the growing season, as doing so produces weak canes and overly dense canopies.

Primocane-fruiting raspberries :

Pruning of primocane-fruiting raspberries involves removing spent canes and pruning primocanes. These activities usually are done in fall and winter.

Primocane-fruiting raspberries are sometimes tipped during the summer to delay fruit set for off-season production in greenhouses/hoophouses or in mildclimate areas. Field-grown primocanefruiting raspberries generally are not summer tipped

in the Pacific Northwest.

Pruning for two crops per year Removing spent-canes :

After the primocane harvest, remove the spent floricanes and the spent, fruit-bearing portion of the primocanes. This upper section normally dies after harvest, but removing it helps reduce disease problems and opens the canopy for easier access.

Although the spent portions of the primocanes can be removed as late as the following spring, late fall through late winter may be the best time to remove them. Primocanefruiting raspberries usually are not thinned to manage cane numbers, other than keeping rows narrowed to about 18 inches.

Pruning primocanes :

Primocane productivity depends on cane diameter and internode length.

Pruning primocanes involves removing canes that are damaged, very thin (pencil width or smaller), too short to train, or outside the hill or row. Primocane pruning can take place anytime during the dormant season. On colder sites in and east of the Cascade Mountains, primocane pruning often is delayed until late winter or early spring (before growth starts), so that the grower can identify and remove winter-damaged canes.

Pruning for one crop per year :

Prune or mow off all canes to 1 to 2 inches above the soil, ideally sometime between December and February. By this time,

the maximum amounts of nutrients, carbohydrates, and other plant reserve compounds have been translocated from the canes into the roots and crowns.

Delaying pruning too long, however, can weaken the plants because stored reserves will move back into the canes and will belost. In this system, the primocanes are not thinned within rows to manage cane density. Doing so reduces yields.

Disposal of prunings :

Many authorities recommend removing prunings from fields and burying or burning them in order to reduce pest and disease carryover. While cane removal is suitable for small plantings, it generally is not practical for large plantations. Where pruning removal is not practical, place the prunings in the alleys between the rows and chop them with a flail mower. Leave the residue on the soil surface to decompos or work it into the soil with a disc or rototiller.

Primocane suppression :

Primocane suppression (also called cane burning, primocane control, or primocane removal) refers to the practice of removing the first flushes of new vegetative canes during the spring when they are approximately 4 to 10 inches tall. Raspberries are unique in that, during the period when floricanes are developing berries, new primocanes are emerging from the crown and roots.

The two types of canes compete for the plant's carbohydrates and nutrients. Theoretically, removing the first one or two flushes of primocanes leaves more carbohydrates and nutrients for

use by floricanes.

The result could be greater fruit set and larger berries. Some research also suggests that the shading produced by tall primocanes reduces light penetration into the canopy, thereby reducing potential fruit numbers. This effect is particularly significant on the lower two-thirds of the floricanes. Primocane removal can be accomplished either by hand or with the use of chemicals. Because hand removal is labor intensive and costly, researchers have studied ways to use herbicides and other chemicals for primocane removal. Because most of these chemicals act by desiccating or "burning back" primocanes and lower fruiting laterals on floricanes, the term "cane burning" was adopted.

During the late 1960s and early 1970s, researchers in the Pacific Northwest and Europe confirmed that yields of red raspberry plants could be enhanced by primocane suppression. Reported yield increases in the Pacific Northwest ranged from 9 to 92 percent when new primocanes were chemically suppressed one, two, or three times using an herbicide. Researchers in Scotland saw similar yield responses when the first one or two flushes of primocanes were removed by hand.

Because of concern that removing primocanes three times each spring might severely reduce cane production in subsequent years, most growers elected to remove primocanes only one or two times each spring.

As of 2005, three compounds were registered in the Pacific Northwest for primocane suppression, although not all of them were registered for all states. Although these compounds generally are effective in removing primocanes and lower fruiting

laterals, few researchers have observed the yield increases reported during the 1970s. Why yields have failed to increase remains unclear, but the reason may relate to the wide spectrum of activity of earlier cane-suppressant chemicals. Besides suppressing the primocanes and lower vegetation, the most popular cane-burning herbicide used during the 1970s and 1980s could be toxic to disease organisms and insect pests. Chemicals labeled for primocane suppression today are effective herbicides, but have little or no effect on other living organisms.

Although yield increases seldom are associated with primocane suppression, the practice continues because it facilitates machine harvest. Besides removing short primocanes, herbicides used for cane burning also remove the leaves and lateral shoots on the lower 1 to 2 feet of the floricanes. Keeping this portion of the canopy clear allows better closure of the catch-plates on machine harvesters and results in less fruit dropping to the ground.

Fruit borne on laterals near the ground rarely is harvested anyway, and it can increase fruit rot within the rest of the canopy. Removing the lower fruiting laterals also reduces disease pressure by increasing air movement around the bases of the plants.

Depending on the herbicide used, primocane suppression also can improve weed control within the plant row, thereby reducing competition from weeds and further improving air movement. Another advantage of primocane suppression is that primocanes that emerge later in the season tend to be shorter at harvest time than canes that develop in early spring. Short primocanes are more resilient and often suffer less damage

from picking machines than do taller primocanes.

Despite the advantages associated with cane burning, this practice should be used only with plants exhibiting moderate to good vigor. A balance between short- and long-term yields must be maintained.

Good primocane development and numbers are essential for sustained production year after year. For that reason, it is essential that primocane suppression not reduce the plants' vigor over the long term.

Research conducted in Scotland showed a reduction in the vigor of a planting with no further yield increases after 4 years of removing the first flush of primocanes by hand. This research was conducted in the 1970s in a vigorous planting of the red raspberry variety 'Glen Clova.'

Although 'Glen Clova' is not considered to be as vigorous as 'Willamette' and other commercial varieties grown in the Pacific Northwest at that time, the finding emphasizes the importance of maintaining adequate primocane growth and vigor for sustained productivity over the life of the planting.

The interaction between primocane vigor and primocane suppression may be particularly important for raspberry growers in and east of the Cascades. Primocane suppression studies have not been reported for the eastern portions of the Pacific Northwest. Of particular concern is the fact that raspberry primocanes growing in cool, short-season areas seldom attain the heights of those in western Oregon and Washington. Before using primocane suppression on large acreages in the eastern Pacific Northwest, conduct small-scale tests for several years

and carefully record data on cane vigor and fruit yield and quality.

Cane-burning herbicides usually are applied in banded applications to the bottom 18 inches of the floricanes when the first flush of primocanes is about 4 to 10 inches tall. The chemicals usually are applied in 50 to 100 gallons of waterper broadcast acre at pressures around 40 pounds per square inch. Surfactants usually are added to the spray mix to increase herbicide effectiveness. One herbicide application usually is adequate, although in cases of exceptional vigor a second application may be desirable. As with all agricultural chemicals, carefully read and follow label directions regarding rates and times of application. Remember that primocane-suppressant herbicides are applied in bands along the rows, rather than being broadcast throughout the plantation.

The objective of the herbicide application is to completely kill to the soil surface all primocanes that have emerged at that time. Primocanes that are not completely killed to the ground continue to grow and tend to produce canes that are brittle, kinked, or multibranched. Such canes are difficult to train and are prone to breakage. In alternate-year cropping systems, primocane suppression can be increased during the cropping year to reduce fruit rot and facilitate harvesting. Although the additional primocane suppression reduces the size and number of primocanes, the plants recover satisfactorily during the noncropping season.

Mulching :

Mulching fruit crops has long been a popular practice and remains valuable for some crops. Mulch can help maintain soil

moisture, reduce soil temperatures, and control weeds. Unfortunately, little research has been published on the effects of mulching raspberries.

In northern Idaho trials, sawdust mulch for weed control was compared with various combinations of hand weeding, cover crops, and preemergence herbicide to determine the effects on fruit yield and quality. After 3 years, fruit yields and quality were similar for all treatments.

Although the sawdust mulch was quite effective in controlling annual weeds, quackgrass and Canada thistle problems became severe by the second year of the trials as weed rhizomes spread through and under the sawdust. When dry, the sawdust repelled water and complicated irrigation. Also, raspberry rootsgrew into the mulch, possibly increasing the risk of drought and freezing injury to the roots. Mulches also provide excellent habitat for voles and other rodent pests, increasing the risk of cane girdling.

Earlier research in another part of the country did show increased yields in summer-bearing red raspberries mulched with straw.

However, due to high material, transport, and application costs, mulching summer-bearing raspberries for weed control in large plantations seems economically questionable.

Research has shown that mulches might play a role in commercial primocanefruiting raspberry production. In New York trials, researchers found that applying straw mulch to newly planted,tissuecultured,primocane-fruiting raspberries improved plant survival and performance.

One of the authors of that study, however, cautions that mulching for weed control after the first year greatly increases the risk of Phytophthora root rot. When using mulches, take care not to keep the soils too moist, as wet soils encourage root rot. All things considered, mulching is probably most valuable for small plantings and might be beneficial for certified organic production systems.

Pollination :

Commercial red raspberries are self fertile. Cross-pollinizing cultivars are not required, and large blocks containing a single cultivar are feasible. Raspberries require insect transfer of pollen from the stamens (male parts of the flower) to the pistils (female parts).

Each raspberry flower contains 100 to 125 pistils, with each pistil representing one potential drupelet. About 75 to 85 drupelets must form in order to produce a normal-looking fruit. Insufficient pollination or fruit set within a flower leads to the development of small, misshapen, and crumbly fruit.

Several processes are involved in developing a mature fruit. The first step involves pollination —the movement of pollen from the male anthers to the female stigmas. Providing that the pollen is viable, the stigma receptive, and the two compatible, the pollen grains begin to grow long tubes that penetrate down the styles and into the ovules. Again, provided that the pollen and the ovule are compatible, the pollen tube can deliver male genetic material into the ovule in a process called fertilization.

Research has shown that bees are responsible for 90 to 95 percent of pollination in red raspberry. Both native bees and do-

mestic honey bees are strongly attracted to raspberry flowers, which produce large amounts of nectar.

Weather plays an important role in pollination. During wet or windy weather and when temperatures are below 50 to 550F, bees tend to remain inactive, particularly domestic honey bees. Bumblebees and other native bees are more likely to be active during inclement weather. While some efforts have been made to manage native bees for pollination purposes, there is little published information on management techniques, and colony failure rates are reported to be high.

For commercial raspberry production, authorities recommend placing at least two beehives per acre of planting. Locate the hives so that flight patterns are not against prevailing winds. The hives should
be in the open and not shaded, with the openings facing south. Keep pans of fresh water near the hives, and place sticks against the sides and bottoms of the pans to enable bees that fall into the water to escape.

Many insecticides are very toxic to bees and should not be used during bloom. If an insecticide application is necessary during bloom, select materials that are least toxic to bees and apply the pesticides in early morning or late evening when bees are inactive. For information on insecticides registered for raspberry production, as well as steps that can be taken to protect bees, refer to the most recent edition of the Pacific Northwest Insect Management Handbook (see “For More Information,” page 97), consult pesticide labels, and work closely with your beekeeper. Also see How to Reduce Bee Poisoning from Pesticides, PNW591.

Water management :

Most commercial raspberry fields in the Pacific Northwest are irrigated. During most years, irrigation helps produce larger fruits, higher yields, and more and larger canes. The amount of irrigation water to apply varies dramatically across the region's soil types and climates.

Types of irrigation systems :

Both overhead and drip irrigation systems are used in commercial raspberry production in the Pacific Northwest. The type of irrigation system depends on planting size, slope of the land, and the availability and cost of water. Where water is abundant and inexpensive, overhead sprinklers often are used. Sprinkler systems are relatively simple and inexpensive to install, and it is easy to locate malfunctioning sprinklers.

Overhead sprinklers also are beneficial if cover crops are grown in the alleys between rows.

On the other hand, sprinklers use large volumes of water, much of which is applied in the alleys. Wet alleys can interfere with access, and irrigating the alleys can increase weed problems. Wet foliage and fruit also can increase disease problems

Sprinkle irrigate early in the morning on dry, sunny days, if possible, to allow the canopy to dry before nightfall.

Trickle or drip irrigation systems are much more efficient than sprinklers at conserving water and placing the water exactly where it is most needed, so they are especially valuable where irrigation water supplies are limited or expensive. In addition, there is no need for labor to move hand lines or other irriga-

tion equipment. Weed problems in alleys are reduced, and the alleys remain dry and accessible. Foliage and fruit remain dry, reducing disease problems. Because relatively little water is applied and water application is confined to the rows, erosion problems, particularly on steeper fields, are reduced.

Washington State University trials comparing drip and overhead irrigation systems for winter squash found that water consumption over a 3-year period was 50 percent less with drip than with overhead systems. Drip irrigation produced 50 percent fewer weeds and 75 percent less weed biomass than did overhead irrigation. Individual fruit weights averaged 83 percent greater in year 1 and 19 percent greater in years 2 and 3 under the drip system.

On the downside, installing the filters, main supply lines, lateral drip lines, pressure regulators, and emitters is time- and labor-intensive, and materials are expensive. Constant vigilance is required to keep filters clear and to locate and repair clogged emitters. Sagging irrigation tubing or trellis wires can create wet spots around the plant crowns and increase the incidence of root rot. Because drip systems do not water the alleys, establishing and maintaining cover crops, particularly perennial ones, can be more challenging with drip than with overhead systems.

Many types of drip and sprinkler irrigation systems are available. Properly designing an irrigation system requires specialized knowledge and experience.

Hiring a system designer with expertise in your type of system generally is a wise investment. Information on irrigation system design and operation is also available from the University of

Idaho, Oregon State University, and Washington State University extension services.

Online and printed catalogs are listed under "For More Information" (page 97). Too much water greatly increases root rot and physiological problems. Too little water creates water stresses that limit cane and fruit development. The critical times for irrigating both summer and fall crops are during bloom and as the berries are increasing in size prior to the first picking. Plantings on medium-heavy soils should be irrigated heavily just before the first picking, and may not need additional irrigation until after harvest. Lighter textured soils may require an extra irrigation before harvest and one or two during harvest.

Water management :

Most commercial raspberry fields in the Pacific Northwest are irrigated. During most years, irrigation helps produce larger fruits, higher yields, and more and larger canes. The amount of irrigation water to apply varies dramatically across the region's soil types and climates.

Types of irrigation systems :

Both overhead and drip irrigation systems are used in commercial raspberry production in the Pacific Northwest. The type of irrigation system depends on planting size, slope of the land, and the availability and cost of water. Where water is abundant and inexpensive, overhead sprinklers often are used. Sprinkler systems are relatively simple and inexpensive to install, and it is easy to locate malfunctioning sprinklers.

Overhead sprinklers also are beneficial if cover crops are grown

in the alleys between rows.

On the other hand, sprinklers use large volumes of water, much of which is applied in the alleys. Wet alleys can interfere with access, and irrigating the alleys can increase weed problems. Wet foliage and fruit also can increase disease problems

Sprinkle irrigate early in the morning on dry, sunny days, if possible, to allow the canopy to dry before nightfall.

Trickle or drip irrigation systems are much more efficient than sprinklers at conserving water and placing the water exactly where it is most needed, so they are especially valuable where irrigation water supplies are limited or expensive. In addition, there is no need for labor to move hand lines or other irrigation equipment. Weed problems in alleys are reduced, and the alleys remain dry and accessible. Foliage and fruit remain dry, reducing disease problems. Because relatively little water is applied and water application is confined to the rows, erosion problems, particularly on steeper fields, are reduced.

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Tools for measuring soil moisture :

Historically, fruit growers judged soil moisture based on feel and experience. Although examining and feeling the soil are valuable methods for determining moisture status, growers now have additional tools to help them make irrigation deci-

sions. Common tools include evaporation pans, tensiometers, and electrical conductance and dielectric units. Some systems can interface with handheld or remote computers for rapid monitoring of multiple stations.

Tensiometers :

consist of hollow, waterfilled tubes that have a pressure gauge on the top and a porous, ceramic tip on the bottom. The tensiometer is buried in the soil within the crop row so that only the gauge and top of the tube are exposed. The gauge registers the difference in water potential between the soil and the water inside the tube. When soils are saturated with water, there is no difference in water potential between the soil and the inside of the tube. As the soil dries, its water potential decreases and the tensiometer registers the difference in water tension. As the soil continues to dry, the tensiometer reading increases. With some experience, a grower can estimate the amount of irrigation water needed based on the tensiometer reading. Tensiometers are most effective for moderate- to heavy-textured soils.

Electrical conductance units :

have been used for years and are increasing in popularity as small, inexpensive, easy-tooperate units have become commercially available. A sensor block, often containing gypsum, is buried within the root zone in the crop row. Several blocks often are buried at different depths. Wires extend from the block to the soil surface and attach to a portable unit that resembles a volt-ohmmeter. With some grower experience and calibration for soil type, electrical conductance units provide rapid, easy estimations of soil water status and irrigation needs. Electrical

units also lend themselves to computer-assisted monitoring and automated irrigation systems.

Dielectric probes :

estimate soil moisture by measuring the dielectric constant of the soil. The dielectric constant of water is much higher than that of the air or mineral components of soil. Some units combine dielectric probes with temperature probes (to measure air and soil temperatures) and rain gauges. Some models allow the information to be broadcast to handheld or office computers or monitors.

Evaporation pans are simple, reliable devices that help determine the time and amount of water to apply. An evaporation pan consists of a copper or stainless steel tub approximately 10 inches deep and 48 inches in diameter. Each day, the grower records the amount of water evaporated and a measure of wind during the preceding 24 hours. Experimentation has helped determine the correlation between water needs for particular crops and evaporation pan data. For raspberries, 1 inch of water usually is applied for each inch of water lost from the evaporation pan. Not every grower needs to maintain an evaporation pan. In topographically uniform areas, one pan per county may be sufficient. University research and Extension centers and other units that report weather data to the National Weather Service often record daily evaporation pan data.

Using evaporation pan measurements You must keep track of rainfall amounts in order to use evaporation pan data. The examples on this page and on page 40 illustrate three ways to use evaporation pan data to plan irrigation. While these examples are based on overhead irrigation, they also apply to drip

systems.

For drip systems, estimate the percentage of the field that requires irrigation and reduce the values in the examples accordingly. For example, if raspberry root zones are 3 feet wide and spaced 10 feet apart, only 33 percent of the field requires irrigation. Apply one-third the amount of water shown in the examples. Experience with your particular irrigation system, soils, and field layouts will allow adjustments to ensure desired moisture levels.

Weed management :

Weeds are plants that are naturally invasive, competitive, and persistent. By competing for light, water, nutrients, and space, weeds reduce the vigor of raspberry plants and decrease berry quantity and quality.

Weeds make harvesting and training more difficult. They harbor raspberry pests and diseases, for example by sheltering insects from insecticide sprays or by acting as secondary hosts for disease pathogens.

Most raspberry rows are about 10 feet apart, with VA- to 2!/2-foot-wide weed-free strips on either side of the row centers. The weed-free strips usually are managed with herbicides. In organic production, weed-free strips usually are maintained through hand weeding or the use of a thick mulch.

In order to effectively manage weeds in raspberries, it is essential to identify which weeds are present. Different weeds are susceptible to different methods of control. Take the time to learn each weed's life cycle before devising an integrated management strategy.

Types of weeds :

Annual weeds

Annuals are plants that complete their life cycle within a single growing season. Most weed seeds in the soil are from annuals. Table 4 lists annual weeds common to the Pacific Northwest. There are two types of weedy annuals. Winter annual weeds usually germinate in the fall or early winter and begin actively growing again in late winter or early spring. Many winter annuals flower, produce seed, and die before summer officially begins. Summer annual weeds tend to germinate in the spring, flower in summer, and die in the fall. In the Pacific Northwest, winter annuals are more prevalent in areas with mild winter climates, while summer annuals predominate in regions with colder winter temperatures.

These designations are not hard and fast, however. For example, not all annuals germinating in the fall are winter annuals. Some summer annuals begin growth in the fall and may not be killed if winter temperatures are mild. These overwintering annuals are particularly difficult to control, given their large root systems and early onset of growth.

Annuals typically are more of a problem in very young or very old raspberry plantings. Before raspberry plants have fully established, leaf canopies can be spotty and relatively thin. This allows light to reach the soil surface, stimulating weed seeds to germinate. Similarly, when raspberry canes decline due to diseases, insects, or poor cultural practices, leaf canopies become thinner, light penetration increases, and annuals again have opportunities to invade.

Annual weeds are easiest to control when they are young. As an annual weed grows, it becomes increasingly difficult to kill, regardless of the control method employed. In addition, seedling annuals are much less likely to compete with raspberry plants than are older annuals. Consequently, weed management efforts should begin as soon as possible after weed seed germination or, in the case of mulching or preemergence herbicides, before germination. With annuals, it is particularly important to prevent seed set, as seeds represent future infestations.

Biennial weeds :

Biennial weeds are species that require two growing seasons to produce seed. Table 5 lists biennial weeds common to the Pacific Northwest.

Biennial weed seeds usually germinate in the spring, but they may sprout any time until fall if soil conditions are favorable. First-year biennials typically form a rosette—a low-growing tangle of leaves that does not produce a true stem. These rosettes remain vegetative until they are exposed to cold temperatures (vernalized) during the winter. Once vernalized, the rosette produces a stalk, flowers, and seeds, after which the plant dies. Under certain conditions, biennials live more than 2 years. This might occur when plants are mowed prior to flowering the second year or if the second winter is especially mild.

Biennials are best managed during their first (vegetative) year of growth, before root carbohydrate reserves build up and the plants' ability to resprout increases. Biennial seedlings can be controlled in the same ways as seedling annuals. Like annuals,

biennials depend on seed production for future infestations. Take care not to allow biennials to go to seed.

Perennial weeds :

Perennial weeds are species that live for 3 or more years. Table 6 lists perennial weeds common to the Pacific Northwest. Some perennials that are not particularly cold hardy often live for only 3 to 5 years, or until cold winter temperatures kill the plants. Such species are termed short-lived perennials.

Perennial weed seeds usually germinate in the spring, but they may sprout any time through fall if soil conditions are favorable. Some first-year perennial plants produce flowers, but most are only vegetative.

Most perennials produce seeds, but many also form vegetative reproductive structures, such as rhizomes, creeping roots, stolons, bulbs, or tubers, that aid in the spread and persistence of the species.

Perennials generally fall into two categories: herbaceous perennials and woody perennials. Herbaceous perennials are plants whose foliage and stems tend to die back to the ground every winter before resprouting in the spring from the roots. Woody perennials are primarily tree and brush species with woody stem tissues that survive above ground by forming relatively heavy bark and dormant winter buds.

Perennial weeds are difficult to manage in perennial crops such as raspberries. If possible, it is always best to control established perennial species before establishing the raspberry block. A combination of frequent tillage and application of translocatable herbicides during the year prior to raspberry

establishment usually will control established perennial weeds. As with biennials, perennial weeds are easiest to kill when they are seedlings.

Methods of weed management :

Hand weeding

Hand weeding can be very selective and effective when weeds are seedlings, before much root growth has occurred. Annuals generally are the easiest type of weed to control by hand, although the crowns of some annual species readily break free from the roots, which are relatively resistant to hand pulling. Unless used repeatedly, hand control rarely is effective against established perennials. Control weeds before they flower, since weeds that have already flowered can mature seed after they have been uprooted.

Cultivation

Most weed seedlings between raspberry rows, whether annual, biennial, or perennial, can be controlled by cultivation. Break weed roots free from the soil so that the plants dry out and die. Cultivating large weeds, or cultivating during damp conditions or late in the day, usually results in poor weed control because roots left in or on the soil tend to reestablish.

Unless done frequently, cultivation should not be used for vegetatively reproducing perennials, such as quackgrass or Canada thistle, as this method cuts up the vegetative structures and often spreads the weed infestation. Cultivate carefully and no more than about 2 to 3 inches deep to avoid damaging raspberry roots.

Mulching

Mulching involves covering the soil surface with natural or synthetic materials to prevent light from reaching the soil surface, thus reducing or eliminating seed germination and often killing recently emerged seedlings. Mulching with organic materials rarely controls established perennials or second-year biennials, as they usually contain enough stored carbohydrate to allow them to grow through all but the thickest mulch.

Mulches also provide a good growth medium for weed seeds that move in after the mulch is in place. Use caution when mulching, given the potential for increased incidence of soil pathogens in moist, cool soils. Mulches also can provide habitat and protection for rodents, insect pests, and slugs.

Weed barriers and fabrics

These sheets of natural or synthetic materials are laid down along the crop rows before planting. Raspberries are transplanted through holes punched along the centerline of the rows. Because these products may interfere with primocane emergence and cultivation practices, they are not widely used in commercial raspberry production.

Depending on thickness and permeability, these materials can effectively control certain established perennial weeds. Other perennials, such as quackgrass, have sharp-tipped shoots that penetrate some fabrics. Identify weed species before using weed barriers.

Herbicides

Herbicides can be selective or nonselective in terms of the plants they kill. Some selective herbicides, for example, kill only grasses, while others kill only broadleaf plants. Nonselective herbicides, such as glyphosate, kill both broadleaves and grasses. Herbicides currently available for use in raspberry rows provide good to excellent control of seedling weeds, but few products adequately control established perennial and second-year biennial in-row weeds.

Always select herbicides based on the weed species present. Correct identification of weeds is an important first step toward control. Application timing and herbicide rates also are critically important to prevent crop injury while achieving effective weed control. Refer to the most recent edition of the Pacific Northwest Weed Management Handbook for a list of herbicides available for use in raspberries.

Mowing

Mowing is a nonselective method of weed control commonly used in raspberry field alleys. Although mowing rarely kills weeds, it reduces their growth and reproductive potential, particularly if the weeds must compete with a cover crop.

Mowing is most effective if repeated during the growing season. Broadleaf weed species are more likely to be injured by mowing than are grass weeds. Many established perennial species are not noticeably injured by mowing because the large amount of carbohydrates stored in their root system allows them to quickly resume growth. Mowing generally is ineffective at controlling low-growing weeds.

Weedergeese :

Weeder geese can help control weeds, particularly in small plantings, and they can be effective in organic production. Weeder geese typically are young (at least 6 weeks of age). They usually are kept within portable electric fences. Move enclosures frequently enough to result in full grazing of weeds, but before raspberry plants are damaged significantly. Weeder geese seem to prefer young grass shoots to broadleaf weeds. Geese can be noisy, and they might require protection against predators and supplemental feed to keep them healthy. At the end of the growing season, the geese usually are sold for human consumption, and new, young geese are purchased the following spring. alley management

The area between weed-free crop rows is known as the alleyway. Many options are available for managing the alleyways in a raspberry planting. One option is to keep them free of vegetation using preand postemergence herbicides or repeated cultivation. This strategy has several disadvantages, however.

- Bare alleys increase the risk of soil loss through erosion and make the soil more susceptible to compaction from tractors and mechanical harvesters.
- Frequent cultivation increases labor, fuel, and machine costs.
- Operating equipment on bare alleys when the ground is muddy can be difficult.
- Exposed soil can become dry and dusty. Dust on raspberry leaves reduces light penetration for photosynthesis and increases the risk of spider mite damage. Dust on fruit lowers its market quality.

For these reasons, the popularity of vegetation-free alleys for

commercial raspberry production has declined. Cover crops are another option for alleyway management. Grass or broadleaf crops in the alleys reduce weed seed germination and can capture soil nutrients that might otherwise be lost to runoff or leaching out of the root zone. These covers help maintain soil organic matter content, reduce soil compaction, and increase cover for predatory insects and ground-dwelling spiders.

A cover crop may consist of one species, such as oats, or multiple species, such as an oat and vetch mix. Grasses do not serve as hosts for several important diseases affecting raspberries and usually are the major components in cover crop mixes. Table 7 lists suggested cover crops, their seeding rates, and establishment characteristics. Table 8 shows the effectiveness of cover crops in suppressing some common Pacific Northwest weeds.

Regardless of the type of cover crop selected, the stand must be dense enough to effectively exclude weeds and prevent weed seed germination within the alleys. Note that cover crops can become infested with perennial weeds through seeds or the spread of vegetative reproductive structures.

The timing of cover crop establishment influences how effectively the cover will control weeds. Because climate zones vary greatly across the Pacific Northwest, consult your seed supplier or local Extension office for recommended sowing times in your area. Delaying cover crop establishment until the second or third year after planting raspberries helps prevent excessive competition with the young raspberry plants.

Cover crop plants may be perennials, which survive for several to many years, or annuals, which require reseeding every year.

Each type has advantages and disadvantages.

Perennial cover crops

The main advantage of a perennial cover crop is that it does not need to be reseeded every year. Permanent covers provide clean, attractive alleys that are comfortable for foot traffic. These advantages are especially important for U-pick operations. A dense stand of a low-maintenance grass, such as 'Companion' (a mixture of fine fescue and perennial ryegrass) helps suppress weeds and provides a good year-round surface for heavy equipment and foot traffic. Shorter, slower growing grasses, such as hard or sheep fescues, minimize the amount of mowing required. A perennial grass cover crop often is called a permanent sod, although the word "permanent" can be misleading. Unless the grass is properly cared for, it generally will thin with time and become weedy, requiring removal and replanting every few years.

The term "sod" also can be misleading. Some grasses, such as sheep and hard fescues, form bunches rather than a dense, intertwined turf or sod. Where frost heaving occurs, bunch grasses suffer much more damage than do rhizomatous grasses.

Perennial grass cover crops do have disadvantages. They interfere with subsoiling in alleyways and with throwing soil from the alleys into the berry rows to maintain raised beds. Thus, permanent sod cover crops can be impractical for growers farming on heavy-textured soils who prefer to subsoil each year. Unless grasses are kept short by mowing, they can provide habitat and protection for mice and other rodent pests. Grass-specific herbicides may be needed to keep the cover

crop from invading the plant rows.

Perennial legumes, such as white clover, also can serve as permanent ground covers. Legumes can fix atmospheric nitrogen, making it available to raspberry plants. The opportunity to use naturally occurring nitrogen in raspberry production appeals particularly to organic growers, who cannot apply conventional chemical nitrogen fertilizers.

Clovers also have disadvantages, of course. Although clover growth can be lush in spring and fall, the plants can die back during winter, exposing the soil to weed establishment or soil loss through erosion, and leaving the soil surface too muddy for field equipment. Pure stands of clover also are less resistant to equipment and foot traffic than grasses. Clover growth can be so lush and aggressive in spring that it is difficult to keep the clover from invading the berry rows. As with permanent grass cover crops, perennial clovers interfere with subsoiling and raised bed maintenance. Clovers can harbor some viruses that infect raspberries.

Clover seeds can survive in the soil for several years, creating the risk of the clover becoming a difficult-to-eradicate weed. Clover seeds are particularly attractive to voles and other rodent pests. For these reasons, some growers prefer not to allow legumes to produce seed. To offset some of the disadvantages of both grasses and clovers, clover-grass mixes sometimes are used.

Annual cover crops

Late summer- or fall-planted annual cover crops provide the benefits of ground cover while allowing subsoiling and other soil management practices. You can till the cover crop into the

soil in the spring or mow and maintain it as weed-suppressant stubble through harvest. Cereal grains, most commonly oats, wheat, barley, or cereal rye, often are used in annual cover crop systems. Winter grains usually are preferred over spring varieties. You can mix cereal grains with winter-hardy legumes, such as Austrian pea or vetch, to help meet the grain's nitrogen needs. Remember to treat the legume seeds with a Rhizobium inoculant before sowing.

Depending on the region, sow grains between early August and mid-September. Western Oregon and Washington growers sow later than those east of the Cascades.

Native vegetation as a cover crop

Managing native vegetation as a cover crop appeals to some growers because it reduces off-farm inputs and requires minimal cost, planning, and effort. In this system, volunteer weeds are allowed to grow and provide ground cover. The weeds typically are managed by mowing or cultivation to minimize or prevent seed formation or weed spread into the plant rows.

Managing volunteer vegetation as a cover crop often is frustrating and unsuccessful. Managing several weed species at the same time can be especially challenging. Cultivation might encourage the spread of certain aggressive and highly competitive weeds, such as quackgrass and Canada thistle. Some weeds also harbor or attract pests, such as plant pathogenic nematodes, diseases, or rodents.

Raspberry Disease and Nematode Management Red raspberry growers in the Pacific Northwest must be able to identify and control many fungal, bacterial, and viral diseases, as well

as disorders caused by nematodes.

Disease control in raspberries is complicated by the fact that both current-season primocanes and secondyear floricanes generally are present.

Researchers estimate that diseases reduce raspberry crops by 10 to 14 percent in most years. In years when weather conditions favor fruit rots, losses can be much higher. Diseases other than fruit rots also cause problems. Raspberry bushy dwarf virus, for example, not only reduces fruit quality due to crumbly berries but also requires more frequent replanting.

To maintain yields and high fruit quality, some virus-infected 'Meeker' fields are replanted after the sixth or seventh harvest season, as compared with about 15 years for healthy plants.

This chapter discusses the major diseases of red raspberries in the Pacific Northwest. For most diseases, the causal organism, symptoms, disease cycle, and control measures are covered. Cultural practices and other nonchemical approaches to disease control are emphasized. Because pesticide regulations and registrations change frequently, this guide does not recommend specific chemicals. For up-to-date information on pesticides registered for red raspberries in this region, refer to the most recent edition of the Pacific Northwest Plant Disease Management Handbook (see "For More Information," page 97). Oregon State University also maintains an Online Guide to Plant Disease Control at http://plant-disease. ippc.orst.edu/ Appendix A (pages 99-100) contains a calendar of activities that describes when to scout for and manage pests.

Diseases that cause symptoms on fruit Gray mold fruit rot and cane Botrytis {Botrytis cinerea) The fungus Botrytis cine-

reainfects many plants and parts of plants. In red raspberry, Botrytis attacks the flowers, fruit, leaves, and canes. Gray mold fruit rot is the most serious fruit disease of red raspberry in this region. Crop losses can exceed 50 percent in years when rains persist through bloom and into harvest and adequate fungicide protection is not provided.

Symptoms Berries are partly or completely covered with tufts of gray fungal growth (Plate 6). In some years, only a few drupelets on a berry become moldy —a condition called “spot rot.” Infected berries rarely leak juice. The fungus often grows on the receptacles left after the berries are picked, covering the receptacles with gray, feltlike spores called conidia. Uninfected receptacles normally shrivel and turn grayishblack. Conidia also infect leaves on both fruiting laterals and primocanes. Infected leaves turn light brown and die. On dead leaves, B. cinereagrows down the petioles and into the canes or laterals. A brown, shield-shape lesion around the node on the cane indicates this type of infection. Under favorable conditions, the lesions continue to expand and may eventually include several nodes. Cane lesions usually exhibit typical concentric “water mark” patterns from fall through early spring. Black sclerotia form beneath the cuticle or outer layer of the canes. Young primocanes may be killed when lesions girdle the vascular tissues. Lesions on older primocanes usually do not kill the canes.

Disease cycle Botrytis cinereaoverwinters as strands of the fungus (mycelium) in leaves and mummified berries and as compact masses of mycelium (sclerotia) on canes. During wet spring conditions, spores (conidia) are produced on infected plant parts. These spores are dispersed mainly by wind, but

some are moved about by splashing rain or irrigation water. The spores germinate in films of water on plant surfaces, and infection can occur within a few hours. Temperatures between 70 and 80oF, combined with rain, dew, fog, or irrigation, provide ideal conditions for Botrytis development. The disease can develop at lower temperatures, but the plant surface must remain wet for longer periods.

During bloom, the fungus colonizes healthy or senescing flower parts, but rarely causes the blossoms to blight, and fruit set is not affected. Flower infections remain dormant until the berries ripen. At that time, the fungus resumes activity, and rot appears. Warm, humid conditions during harvest favor fruit rot. Control No single cultural practice provides adequate Botrytis control. During years when disease pressure is low, integrating several cultural practices might provide adequate control. In years with moderate to high disease pressure, cultural practices alone probably will not be adequate. Cultivars differ slightly in susceptibility to Botrytis, but all are susceptible, and even relatively resistant cultivars can be damaged when disease pressure is high.

Cultural control. Sanitation provides few advantages because the fungus attacks and survives on a wide range of crop and weed plants and plant debris. Cultural control practices include the following.

• Create an open canopy to improve air circulation and drying of the foliage, stems, and fruit. A divided canopy supported on a V-trellis, with canes fastened individually to the trellis instead of in bundles can reduce Botrytis problems. Follow the pruning recommendations in Chapter 5 to prevent overcrowded canes from inhibiting air circulation.

• Avoid excessive nitrogen fertilization.
• Pick fruit during the coolest part of the day.
• Pick frequently so that berries do not become overripe.
• Keep harvested berries in the shade and move them to refrigerated storage as soon as possible to remove field heat.
• Control early-season primocane growth mechanically or chemically (see "Primocane suppression) .
• Schedule overhead irrigation for early morning just before the sun comes up so that plants dry quickly.
• Install a drip irrigation system to minimize wetting of plant surfaces. Chemical control. Refer to the Pacific Northwest Plant Disease Management Handbook for products registered for control of gray mold.
• Employ fungicide resistance management strategies, such as alternating fungicides and tank mixtures. Pay close attention to the fungicide mode of action group number and avoid repeated use of products from the same group.
• Begin fungicide applications at early bloom to protect newly opening flowers.

Phytophthora root :

rot {Phytophthorafragariaevar. rubi) Tomato ringspot virus Yellow rust (Phragmidiumrubi-idaei) Diseases that cause symptoms on canes and leaves Cane blight {Leptosphaeriaconiothyrium) The fungus Leptosphaeriaconiothyrium causes this cane disease. It enters the primocanes only through wounds, so any practice that minimizes wounding is beneficial.

Wounds become less susceptible as they heal, and primocanes are more difficult to wound as they become older. Berry-catching plates on mechanical harvesters are the main source of wounds to raspberry plants. Primocanes, particularly those

on the outside of each plant, are scraped with each pass of a mechanical harvester.

Several passes may be needed before a cane is wounded deeply enough for the fungus to gain entry to the vascular tissues.

Cane blight rarely is a problem in hand-harvested fields. Symptoms Except for the wound itself, symptoms do not appear on the canes until fall or during the fruiting year. The area of the wound often is flattened and cracked.

Because the fungus degrades cellulose, infected canes are easily broken at the wound. The surfaces of the cane around the wound turn grayish-black as fruiting bodies form beneath the epidermis. The surface appears sooty when spores (conidia) ooze onto the cane following rainy weather.

Diagnostic lesions develop in the vascular tissue but are not visible unless the tissue is exposed by scraping a suspect cane with the blade of a knife. Healthy vascular tissue is moist and pale green. In contrast, dry, orange-red to brick-red lesions form in the vascular tissue of diseased canes.

The fungus remains in the vicinity of the wound. The lesions, called “stripe lesions,” extend mostly above and somewhat below the wound site. Occasionally, they extend the full length of the cane.

Severely infected canes often are girdled. Depending on the extent and location of vascular damage, symptoms the following spring range from failure of a few buds to death of the cane above the point of girdling. Disease cycle The fungus overwinters on old cane stubs and near wounds on infected fruiting

canes. During rainy weather, conidial spores ooze onto the surface of the canes and can be moved to wounds by splashing rain or irrigation water or by contaminated harvester catching plates. Ascospores are discharged into the air from a second type of fruiting body found mainly on old cane stubs. The role and importance of ascospores in the disease are not clearly understood.

Cultural control :

- Remove wounded and infected canes.
- Prune close to the ground because the fungus overwinters on old cane stubs.
- Irrigate in early morning to reduce the time plants remain wet.
- Convert from overhead irrigation to a drip system.
- Remove early flushes of primocanes
- Convert to an alternate-year cropping system (see page 3).
- Clean and lubricate berry-catching plates frequently during harvest.
- Use springs with just enough tension to close the catching plates.

Chemical control :

Fungicides are registered for raspberry cane blight, although currently registered products do not always provide acceptable control.

Crown gall :

{Agrobacterium tumefaciens and A. rubi) Pseudomonas blight {Pseudomonas syringaepv. syringae) The bacterium Pseudomonas syringae pv. syringae is the causal agent of this occasional disease of red raspberry.

Symptoms Symptoms first appear in early spring as brownish, water-soaked spots on the leaves, petioles, and internodes of young fruiting laterals and emerging primo canes. The spots become larger and darker, with streaks extending from the damaged parts into the vascular tissues. When symptoms are severe, entire laterals and primocanes may be killed. Generally, the observable infections and symptoms cease by about mid-May.

Pseudomonas symptoms can be confused with other raspberry diseases and disorders. Leaves infected by spur blight appear similar to Pseudomonas-infected leaves, but do not blacken. The raspberry cane borer can cause the tips of laterals to blacken, similar to Pseudomonas blight.

Borer-infested canes readily break off near the soil, and a larva often can be found in the tunnels. Some herbicides can cause damage that mimics symptoms of Pseudomonas blight.

Symptoms of leaf spotting and black streaking under the bark of primocanes (in the cambium layer) also occur in the autumn but are easily missed. The presence of symptoms in autumn often is associated with continued cane growth due to excessive nitrogen fertilization, early topping of primocanes, or resumption of growth following summer drought.

Cultural control :

• Highly resistant cultivars include 'Chilcotin' and 'Newburgh.' 'Meeker,' 'Willamette,' and 'Sumner' show an intermediate reaction, while 'Nootka' is highly susceptible.
• Avoid overfertilization.

Chemical control :

Various copper-containing fungicides are used to reduce the populations of bacteria on canes and buds.

Raspberry bushy dwarf virus This disease is caused by raspberry bushy dwarf virus (RBDV). The name of this disease is misleading, as infected plants are neither bushy nor dwarfed, although primocane growth may be reduced. In a British Columbia field trial when 'Meeker' plants were inoculated with RBDV, primocane growth was reduced by 22 percent, cane diameter by 14 percent, and fruit yield by 72 percent compared to uninoculated plants.
The life span of a healthy planting is typically about 15 years. Fields with a high percentage of RBDV-infected plants and crumbly fruit are replanted every 7 to 8 years. Some growers remove fields after the fifth harvest season when the disease has spread quickly and fruit quality has declined.

RBDV is pollen-borne, but it does not kill the pollen. Flowers are routinely visited by pollen- and nectar-collecting insects, including honey bees. These insects efficiently move virus-laden pollen from flowers on infected plants to flowers on uninfected plants, thus spreading the virus.

Symptoms :

The virus is symptomless on the leaves of many red raspberry cultivars. In others it causes rings and line patterns on leaves and yellowing of leaf tissue between the veins (Plate 9). The virus causes young drupelets to abort, leading to crumbly berries and a reduction in fruit quality.

Control :

• Use certified plants known to be free of the virus.
• Plant cultivars, such as 'Willamette' and 'Chilcotin,' that are immune to the virus. 'Haida,' 'Comox,' and 'Heritage' are moderately resistant, and 'Cowichan' may be immune.
• Plant new fields as far as possible from fields with infected plants.
• Plant in large blocks to slow the movement of the virus into new plantings.
• Place honey bee hives in the centers of new fields, rather than along the edge, to reduce the risk of bees carrying the virus in from nearby fields that contain infected plants.

Thimbleberry (Rubusparviflorus) is a wild host for RBDV. Remove thimbleberries from areas near raspberry fields.

Spur blight {Didymellaapplanata) This cane and foliar disease in caused by the fungus Didymellaapplanata. The fungus attacks black raspberry, blackberry, and raspberry-blackberry hybrids, in addition to red raspberry.

Spur blight results in significant yield losses, particularly in vigorous plantings when excessive nitrogen fertilizer is applied.

Symptoms :

Numerous brown, necrotic spots with yellow borders form on leaves in years when rainy weather persists into late spring. If the disease is severe, infected leaves yellow and drop prematurely, often causing ripening berries to wither. Symptoms on primocane leaves first appear by midsummer as brown, wedge-shape lesions with yellow borders (Plate 10).

These spots usually are centered on a vein. The lesion starts at the tip of the leaf blade and points toward the petiole. The fungus grows through the petiole and invades the cane, producing a brown lesion around the bud. The lesion may appear purple on raspberry cultivars that have a waxy bloom on the cane surfaces.

Cane lesions usually appear first at nodes on the lower portions of the primocanes and then infect progressively higher nodes.

Lesions seem to disappear later in the fall when primocanes turn brown as they mature for winter.
During winter, infected areas turn silver-gray, and small, black fruiting bodies of the fungus develop on the lesions. Buds at infected nodes are smaller and less likely to grow into a strong fruiting lateral or spur during the fruiting year than buds at healthy nodes. Extended periods of mild weather in the fall may increase bud failure the following spring.

Disease cycle :

The fungus overwinters in two types of fruiting bodies in cane lesions. Ascospores (sexual spores) are discharged into the air from April through August. Conidia (asexual spores) ooze from pycnidia throughout the summer and are disseminated by splashing water. Both ascospores and conidia can infect leaves.

Cultural control :

• Remove and destroy old fruiting canes.
• Keep plant rows narrow and avoid excessive fertilization. Keep the plant canopy open to ensure rapid drying of leaves and canes.

• If using an overhead irrigation system, irrigate early in the morning to shorten the time canes and leaves remain wet.
• Primocane suppression has proven helpful in controlling spur blight
• 'Haida' and 'Chilliwack' are reported to have field resistance. 'Willamette' is considered tolerant. Although it is readily infected by the fungus, 'Willamette' produces a satisfactory crop even when disease pressure is high.

Chemical control :

• A delayed dormant application of limesulfur helps reduce the amount of overwintering inoculum.
• Fungicides are registered for control of spur blight. If applied from just before bloom until after harvest, they protect the foliage on fruiting canes and primocanes. If leaf infections are controlled, cane lesions do not develop.

Tomato ringspot virus :

Tomato ringspot virus (TomRSV) is transmitted by the soil-borne dagger nematode Xiphinemaamericanumand possibly related species. Besides red raspberry, the virus infects some cultivated and wild blackberries and raspberry-blackberry hybrids such as 'Boysen.' The native hosts of TomRSV and the dagger nematode are numerous and include many common weeds such as dandelion and chickweed.

These plants can serve as sources of inoculum in and around raspberry fields. The rate of natural spread is about 6 to 8 feet per year along the row, while the spread from row to row is slower.

An infected nematode can transmit the virus to plant hosts for several months.

Soil adhering to machinery can move the infected nematodes within fields and to other fields. In the absence of the virus, the dagger nematode causes little direct damage to raspberries.

Symptoms :

The appearance of symptoms in red raspberry depends on the cultivar, time of year, and how long the plants have been infected. Symptoms usually are most noticeable in newly infected plants.

Leaf symptoms are varied and include mottling, chlorosis, curling, and ringspotting (Plate 11). TomRSV also may cause crumbly fruit. Some cultivars exhibit severe dwarfing that resembles cane symptoms of Phytophthora root rot.

Control :

• Test soil from potential raspberry sites for the dagger nematode the year before planting. Because of the wide host range of TomRSV, it is important to have new land (as well as ground previously planted to raspberries) tested.
• Fumigate the site based on the results of the soil test for nematodes. Postplant applications of nematicides have not been effective against the dagger nematode.

For this reason, it is important to know whether these nematodes are present in the soil well before planting when there is time for corrective action.
• Use certified planting stock known to be free of TomRSV.
• Dig out and destroy diseased plants. Remove five plants from ei-

ther side of infected plants.

• Clean equipment thoroughly to remove soil containing nematodes before moving into other fields.

• Begin operations in fields that do not contain the dagger nematode and then move into fields with infested soil.

• Control weeds. Not only are certain weeds hosts of the nematode and the virus, but the virus can be seed-borne.

Yellow rust :

(Phragmidiumrubi-idaei) Yellow rust disease, sometimes called western yellow rust or cane rust, is caused by the fungus Phragmidiumrubi-idaei. Severe outbreaks that occurred during the mid-1990s were attributed to the appearance of a new race of the fungus that attacks 'Meeker' and to changes in cultural practices that favored rapid disease buildup.

The fungus has a complex life cycle with five different spore stages. Different symptoms are associated with four stages. The fungus completes its life cycle entirely on the red raspberry plant and does not need an alternate host, as do many other rust fungi.

Symptoms and disease cycle The fungus overwinters as thick-walled, resting spores (teliospores) attached to canes and leaf debris. In early spring, around the time of bud break, these spores germinate to produce another type of spore (basidiospore) that infects newly expanding leaves. The first symptoms appear in spring—greenish-orange, glossy, pimplelike structures (spermagonia) about 1 millimeter (‘/as inch) in diameter on the upper surfaces of young leaves on floricane laterals.

These structures tend to be inconspicuous unless abundant.

Within a few weeks, bright yellow fruiting bodies (aecia) form in one or two concentric rings around the structures. Yellow, powdery spores released from the fruiting bodies lead to the formation of rust pustules on the lower surfaces of the leaves from late spring through fall. These rust pustules produce masses of powdery, pale yellow spores called urediniospores that reinfect leaves, leading to the development of more rust pustules (Plate 12).
This repeating stage of the life cycle allows the disease to build up rapidly during the summer, when environmental conditions are favorable, and causes most of the damage to raspberry plants. Leaf tissues above the rust pustules turn yellow, then brown, and eventually die.

When leaves on the fruiting laterals die, the developing be ries fail to ripen. Infected leaves on primocanes also die prematurely, which can stunt primocane growth. Pustules occasionally form on flower sepals, red drupelets, and primocanes.

By midsummer, dark brown, teliosporebearing fruiting bodies begin to develop within the rust pustules, turning the once yellow pustules almost black. Severely infected primocanes break easily when being trained to the trellis. Pustules that deeply wound primocanes serve as entry points for the cane blight fungus, Leptosphaeria coniothyrium.

Cultural control :

• Historically, burying old leaves and spent fruiting canes by cultivating was the main means of controlling yellow rust. This method is not always effective, however.
• Tie canes to the trellis after the leaves have fallen in late fall or early winter. Some growers prefer to tie primocanes to the trellis

shortly after harvest; however, at this time of year, the primocanes still have most of their leaves, leaving large quantities of overwintering spores in the tops of the plants. Infected leaves also hold moisture and create an ideal environment for teliospore germination in early spring. In this situation, yellow rust begins at the top of the plant the following year, rather than starting at the plant base and moving upward.

• Primocane suppression helps to control yellow rust by eliminating susceptible tissues when spermagonia and aecia are present on fruiting cane leaves.

• Controlling cane vigor improves air circulation in the plant canopy and hastens the drying of leaves and canes.

• 'Meeker,' 'Willamette,' and 'Tulameen' are susceptible to yellow rust.

Only 'Chilcotin' remained free of yellow rust in a field planting and laboratory inoculation tests. 'Meeker' once was thought to be partially resistant because the disease developed slowly on that cultivar. Tests, however, have identified a new race of the fungus that develops as rapidly on 'Meeker' as it does on other susceptible varieties.

Chemical control :

A delayed dormant application of liquid lime-sulfur kills teliospores and basidiospores on canes. This treatment probably is not effective in reducing the vast numbers of teliospores in leaf debris trapped along the top trellis wire. Other fungicides are registered to control this disease. See the Pacific Northwest Disease Management Handbook for registered fungicides.

Diseases that cause symptoms on roots Armillaria root rot {Armillariasw.)

This root disease is caused by species of the native soil-borne fungus Armillaria. The fungus damages the roots of many economically important trees and horticultural crops.

Although the disease is not common, infected plants usually die. The disease often appears in patches within raspberry fields.

Symptoms :

Usually the first symptom is the decline and dieback of canes. The leaves on infected canes yellow, wilt, and die. Initially, just one or a few canes on a plant may be affected, indicating that only a portion of the root system or crown has been damaged.

White, feltlike masses of fungal growth are found between the bark and the wood at or below the soil line. Black shoestring-like strands, called rhizomorphs, are found among the roots. These hard fungal structures can grow considerable distances through the soil and may be one way that the fungus spreads between plants.

Rhizomorphs can be mistaken for roots, but roots are solid and rhizomorphs are hollow. In autumn, honey-colored mushrooms may form on the crowns of infected plants, releasing clouds of spores that are widely dispersed.

Disease cycle :

The Armillaria fungus can survive for years in soil and infested root debris. Its ability to survive on dead plant material, which may be several feet below the soil surface, makes control diffi-

cult. Roots of raspberries usually are attacked when the fungus spreads from underground woody material, such as pieces of old tree roots. Infection can occur when roots come in contact with rhizomorphs.

Cultural control :

• Remove and destroy infected plants, including as many small roots as possible. Also remove healthy plants immediately djacent to infected ones. Avoid setting new plants where infec ed plants were removed.
• Take precautions when planting raspberries on a site cleared of trees, shrubs, or brush. Girdle large trees and allow them to die before removal. Thishastens the decay of roots, and roots depleted of nutrients are less likely to support fungal growth when the tree tops are removed. Remove and burn, onsite, all roots greater than 1 inch in diameter. Obtain a burning permit, if required. If possible, leave the site fallow for at least 1 year. Up to 4 fallow years are recommended.
• When the source of inoculum cannot be removed, trenches lined with plastic sheeting may prevent contact between crop roots and inoculum.
• Maintain plant vigor using sound cultural practices. Plants may be predisposed to attack when the soil is too dry.

Whether using overhead or drip irrigation, deep irrigation is recommended.

Irrigate to fill the entire root zone. Sawdust mulch made from infected trees can introduce Armillaria into a field. As mentioned earlier, sawdust mulch creates other problems in raspberry fields and is not recommended.

Chemical control :

When combined with the removal of infected roots, soil fumigation with methyl bromide has provided the best, although still limited, control of Armillaria. The use of methyl bromide, however, is being phased out. Refer to the Pacific Northwest Plant Disease Management Handbook for other treatment options.

Crown gall :

{Agrobacterium tumefaciens and A. rubi) Agrobacterium tumefaciensand A. rubi are the two bacterial pathogens associated with crown gall formation on Rubus. The pathogen is widespread in soil and can infect herbaceous and woody plants from many plant families.

These bacteria are wound pathogens, and infection occurs through injuries to the crown and roots. Natural wounds include lateral root formation, leaf scars, and winter injury.

Mechanical injuries occur during pruning, training, and harvesting. Infections occurring during the first growing season after planting are the most severe and can stunt or kill plants. Crown gall is more severe in the presence of the root lesion nematode and root-attacking insects.

Symptoms and disease cycle :

The formation of galls on the crowns or roots is the most diagnostic symptom. Galls also may form at pruning wounds or where canes have been injured by bending or training. Galls are a spherical mass of disorganized tissues and usually are soft and spongy (Plate 13). They first appear in spring with the

beginning of warm weather and increase in size during the summer.

As galls grow larger, infected canes split and dry out. Symptoms on severely infected canes include stunting, leaf chlorosis, small and seedy fruit, wilting, and possibly death. In fall, galls near the soil darken and begin to break down.

Cultural control :

• Establish plantings in uninfested soil wherever possible.
• Avoid fields where the previous crop was susceptible to crown gall. Sites previously planted to nonhost crops, such as grasses, are preferred.
• Use certified nursery stock grown in fields where the disease has not been found.
• Thoroughly inspect planting stock and use only plants free of galls.
• Plant resistant cultivars. 'Willamette' is highly resistant, and 'Nootka' and 'Canby' have intermediate resistance in the absence of nematode damage. 'Skeena,' 'Chilliwack,' 'Coho,' and 'Haida' are susceptible.
• Preplant soil solarization may be beneficial depending on field size, location, and climate. Place clear plastic over well-tilled soil that has been irrigated to near field capacity. Solarize from mid-July through late September and plant the following spring.

Chemical control :

• A chemical to control this disease was registered for Oregon and Washington in 2004Biological control
• Dip the roots and crowns of raspberry planting stock into commercial suspensions ofAgrobacteriumradiobacter strain K84 or

strain K1026 before planting.

Phytophthora root rot :

(Phytophthorafragariaevar. rubi) This root rot is caused by the soil-borne funguslike microorganism Phytophthora fragariae-var. rubi and is the most serious root disease of red raspberry in the Pacific Northwest. It usually is associated with poor water drainage caused by heavy soils, hardpans, excessive irrigation, or similar conditions.

Soil at or very near saturation is required for the production and dispersal of infective zoospores. Saturated soil conditions may favor activity of the pathogen and, at the same time, stress the root system. The pathogen is least active when soil temperatures exceed 680F.

Other Phytophthora species also may be involved. Root lesion nematode and possibly the dagger nematode may contribute to disease severity, particularly in northern Washington.

Symptoms :

The most visible symptom of root rot is the death of primocanes and fruiting canes. The fungus attacks and kills some primocanes before they reach the soil surface.

Additional infected primocanes are removed during primocane suppression before they wilt. Wilting often coincides with the onset of hot, dry conditions. Primocanes usually begin to wilt from the tip down.

The tips wilt over, exposing the silvery undersurfaces of the leaves. Leaves on infected canes often turn yellow, sometimes with reddish-brown streaks, become stiff and brittle, and die.

The margins of wilted leaves often become necrotic before the rest of the leaf dies, and the wilted leaves form flags by remaining attached to the petioles.

One or a few primocanes in a plant may die while the rest remain healthy, depending on the health of the portion of the root system supporting the particular canes. Some primocanes that seem healthy when tied to the trellis in the fall die during the winter.

Floricane collapse can occur at any time during the growing season, depending on the extent of root damage and environmental conditions. Berries on affected fruiting canes are small and wither before ripening or just as they begin ripening.

An examination of the roots generally reveals a lack of fine feeder roots and dead structural roots. The internal color of healthy roots is creamy white to tan, while that of infected roots is brick-red, cinnamon, or dark brown. A sharp transition zone usually is present between infected and healthy root tissues. A dark, water-soaked lesion extends several inches up from the bases of many diseased primocanes.

Cane wilting can be caused by other factors, including cane blight and crown borer. A definitive diagnosis of Phytophthora requires a plant clinic culture of the fungus from infected roots or a molecular test to detect the pathogen.

Cultural control :

No single cultural practice or chemical is likely to provide effective control. Combine several cultural and chemical practices in an integrated program for best results.

• If possible, select sites with welldrained sandy or sandy-loam

soils.

• Modify poorly drained sites by installing drain lines. Plant only certified planting stock or plants propagated by tissue culture.

• For new plantations, plant on raised beds 12 to 18 inches high.

On established fields where the raspberries are on flat ground, some growers have developed raised beds by throwing 8 to 10 inches of soil from the alleys around the bases of dormant plants in the fall.

Roots grow from the entire underground portions of new primocanes as they push through the added layer of soil. If yearly additions of soil are made for 2 or 3 years, most of the root system will be in the raised bed, where the soil is drier during the rainy winter months.

CAUTION: Plants on raised beds require closer attention to soil moisture during the summer, as soil in the beds dries faster. Also, water from rain and overhead irrigation tends to run off the beds instead of percolating through them.

To alleviate these potential problems, many growers have changed from overhead to drip irrigation systems, sometimes using two drip tapes per row.

• Gypsum, incorporated at 6 tons per acre before planting, helps to suppress Phytophthora activity and provides some control.

• If raised beds are not used, slope the soil in the alleys so that water drains away from the plants.

• Subsoil in the alleys to facilitate water drainage.

• Preplan! soil solarization has delayed the appearance of root rot symptoms for about 2 years. Place clear plastic over rototilled soil that has been irrigated to field capacity. Solarize for about 8 weeks during the sunniest part of the summer in preparation for planting

the following spring. Solarization has not proven effective in Idaho's cool climate.

• Plant cultivars that are resistant or tolerant to root rot. 'Chilliwack,' 'Meeker,' and 'Sumner' are moderately resistant. In Idaho trials, 'Killarney' and 'Summit' have performed well on heavily infected soils. 'Meeker' has some field tolerance once plants become established.

Other cultivars have varying degrees of resistance to Phytophthora. Refer to Chapter 3, "Cultivar Selection," for details. The development of new cultivars that combine resistance with desirable horticultural traits remains a high priority of regional raspberry breeding programs.

Chemical control :

• Fungicides are registered for control of Phytophthora root rot in red raspberries. Some fungicides are applied to the soil, while others are applied to the leaves during the growing season.

• Soil fumigation can delay the onset of root rot for several years but does not eliminate the problem. Fumigants used solely for nematode control have not been effective against root rot.

Nematodes :

Dagger nematode (Xiphinemaamericanumgroup) The nematode Xiphinemaamericanum and related species, collectively known as the X. americanumgroup, feed on raspberry roots and transmit tomato ringspot virus.

Dagger nematodes are migratory in soil and are called ectoparasites because they live outside the roots. Only their long, needlelike stylets penetrate into the root tissue to feed and

transmit viruses.

Symptoms :

In the absence of tomato ringspot virus, extensive feeding by one species in the group, X. bakeri, causes swellings and fish-hook-like curling of the root tips.

Stunting of the roots leads to reduced cane growth. The decline is similar to that described for plants attacked by the lesion nematode. Other species in the group cause little direct root damage. See “Tomato ringspot virus” (page 69) for more information.

Cultural control :

• Use certified planting stock from fields known to be free of the dagger nematode and tomato ringspot virus.
• Plant in soil that has been tested and found free of the dagger nematode. Collect soil samples between December and April at least 2 years before planting. If the nematode is detected, plant a shallow-rooted grass crop for 2 years. The shallow roots bring the nematodes to the upper portion of the soil profile, where they are more easily controlled with fumigants. Planting a nonhost crop reduces virus inoculum because the nematodes cannot reacquire the virus.

Chemical control :

• Preplan! soil fumigation is helpful in managing this pest.
Root lesion nematode [Pratylenchusspp.) While several species of root lesion nematodes (Pratylenchusspp.) have been associated with Rubusspp., only P. penetrans seems to cause signifi-

cant root damage.

Pratylenchuspenetransis a migratory endoparasite that spends part of its life in soil and part in root tissues.

Symptoms :

Small, elongated, discolored lesions appear on new roots of lightly or newly infected plants. The fine feeder roots die as the damage increases. This damage stimulates the formation of many fine roots and a witches' broom appearance. Without feeder roots, the larger diameter roots are unable to take up nutrients and water and often are invaded by secondary fungi. Aboveground symptoms are most often observed on fruiting canes and include reduced cane number and diameter, stunting, and off-color leaves.

Cultural control :

• Select sites that are free of root lesion nematodes. Sample the soil 1 year before planting to allow time for treatment if lesion nematodes are detected. Include soil and roots in samples sent for nematode analysis. Root lesion nematode populations usually are highest in late summer and fall.
• Use certified planting stock.
• Nematodes are transported in soil and water. Because infested soil can be moved on farm machinery, always work fumigated and noninfested fields first before moving to nematode-infested fields. Thoroughly clean machinery after leaving infested fields.

Chemical control :

• Preplant soil fumigation in the fall or spring before planting has

proven helpful in controlling root lesion nematodes.

• Postplant soil treatments are available.

▸ Harvesting and Postharvest Consideations :

Raspberry harvest in the Pacific Northwest begins in late June or early July and lasts for about 3 to 8 weeks, depending on the area and cultivars grown. In primocane- fruiting cultivars, the second harvest occurs from July through September, depending on cultivar and weather conditions.

Because raspberries are fragile, have a short shelf life, and ripen over several weeks, frequent picking is necessary. While careful harvesting is important for all crops, it is especially important for raspberries.

Once picked, the berries must be kept as cool as possible and transported quickly to processors or refrigerated facilities to prepare them for shipment to consumers.

Mechanical harvesting :

The 1987 edition of this guide focused primarily on hand harvesting. Much has changed since then. Today, more than 90 percent of the raspberries produced in Washington and Oregon are mechanically harvested. In Idaho, raspberries are grown on smaller acreages, primarily for direct sale to local fresh markets, and almost all fruit is hand harvested. The shift to mechanical harvesting occurred primarily due to labor costs.

Hand harvesting can account for up to two-thirds of the total

labor cost for fruit production. When migrant labor was inexpensive and abundant, hand harvesting was feasible. With changes in immigration policies and regional economies, farm labor pools have declined. Growers must pay far more for wages, housing, education, and health benefits than ever before.

Facing increased labor costs and competition from other states and countries, many Oregon and Washington raspberry growers adopted mechanical harvesting systems. A typical mechanical harvester with 1 operator and 4 field graders can do the work of 80 to 85 hand pickers.

Aside from decreased labor costs, mechanical harvesting has other advantages. Harvesting machines can operate at night when hand picking is not practical. The lower nighttime temperatures and higher humidity help keep fruit quality high.

Compared with hand-harvested fruit, machine-harvested raspberries may be more uniformly ripe. With hand picking, many berries are harvested before they are completely ripe; thus, they have not reached their full size and quality.

Properly adjusted mechanical harvesters primarily remove fully ripe fruit that has formed an abscission zone between the fruit and receptacle. Increased fruit uniformity translates into berries that are larger, better colored, and have lower acidity and higher total soluble solids.

Mechanical harvesters do have disadvantages. All require significant capital investments and ongoing expenses for maintenance and repair. Alternatives to purchasing equipment exist, however. Some companies lease machines, and some growers do custom machineharvesting work.

Machine harvesting reduces a grower's flexibility in terms of cultural practices and fruit usage. Row spacing and trellises must be designed with the harvesting equipment in mind. Generally, this means using a narrow "I" trellis without cross arms. Although machine harvesting is possible with hedgerows, most Pacific Northwest growers who harvest by machine use hill systems and arc training. Alleys must be maintained so as to support the harvester's large wheels and prevent excessive compaction. Irrigation must avoid creating muddy alleys that could interfere with harvester movement and operation.

Finally, damage to canes by mechanical harvesters has greatly increased the incidence of cane blight.

Cultivars must be suited to mechanical harvesting. Raspberry cultivars with fruiting laterals that are too short, too long, or brittle machine harvest poorly.

Damage to fruit during harvesting was more common and severe using earlygeneration machines and training systems. Today, machine-harvested fruit quality is quite good. Nonetheless, mechanically harvested raspberries are not suited for fresh market sales.

Pest control generally is more important with machine-harvested crops than handharvested crops. Beetles, caterpillars, and other insects can become serious contaminants as they are shaken from the canes into the harvester. In organic production systems, insects and predators that might otherwise be considered beneficial can end up as contaminants in a machine-harvested product. Specific pests and control practices are discussed in Chapter 8.

Various mechanical raspberry harvesters are commercially available, although most operate similarly. Before investing in planting stock, trellises, irrigation systems, and equipment, consult with harvester manufacturers to select a harvester and design an operation compatible with that equipment. Mechanical harvesters can be tractor drawn or self propelled. Larger machines usually are self propelled. The machine straddles the raspberry row, so that the canes are in a narrow opening running the length of the machine (photo, page 91).

Rows of flexible horizontal bars or "fingers" (also called "beaters") on each side of the crop row gently shake the fruiting laterals, trellis wires, and canes, causing the ripe fruits to drop off. Inclined catch plates about 12 to 15 inches above the ground collect the falling fruits. From the plates, the berries travel on conveyor belts across screens, where fans remove some contaminants. The fruits then are carried across a short inspection belt, where graders remove additional contaminants, and then into flats or other containers.

Harvesters usually travel about 1 mile per hour down the rows, with the fingers shaking at 100 to 150 beats per minute. Weights are used to increase beater speed as the season progresses. These adjustments, coupled with machine harvester speed, allow a good driver to adjust picking severity such that only ripe fruit is removed and there is little damage to the plant or remaining crop.

Hydraulic systems allow harvesters to be raised or lowered to accommodate different training systems. Most machines also can be tilted from side-to-side to provide level operation on sloping fields.

Summer-bearing red raspberries are machine harvested every 2 or 3 days to minimize loss of ripe fruit. Thus, there may be 10 to 15 harvests per season depending on cultivar and climate. Waiting too long between harvests increases fruit losses on the ground. Research has show that typical losses for machine harvest are 16 percent of total yield over the length of the season. Of course, there also are losses when raspberries are hand picked; these losses are estimated to be 5 to 10 percentof total yield. Hand harvesting Hand harvesting remains important for small farms and larger operations that focus on high-quality, fresh market fruit or high-quality IQF fruit. Because of the greater harvest costs, fruits for the fresh market bring a substantial premium compared with processing berries. As shown in Table, processing red raspberries in Oregon and Washington have averaged about $0.60 per pound in recent years, compared with $1.50 for fresh market berries.

The number of hand pickers required per acre depends on the crop load, weather, and workers' skills. Five or six pickers per acre may be enough for the first and last pickings. The main crop likely will require 10 to 12 pickers, and the peak harvest during warm weather may require 15 to 20 skilled pickers per acre.

Worker skill is important. A beginning picker may be able to harvest only 40 pounds per 6-hour day. Experienced pickers usually can harvest 60 pounds, and highly skilled pickers may be able to harvest more than 100 pounds of red raspberries per day.

The picking interval varies with the stage of harvest, cultivar, and weather conditions.

Five or 6 days may pass between the first and second pickings, with 2 or 3 days being more common during the peak season or warm weather. Particularly for growers whose harvests begin in late June, the Fourth of July holiday can be challenging when it create a long weekend. Advance planning is a must to prevent crop loss. Options include particularly careful picking just before the weekend or offering bonuses for workers who pick during the holiday.

To maintain high fruit quality in harvested berries, diseased fruits should be removed from the canes. At a minimum, drop them into the centers of the alleys.

A better practice is to remove them from the field to prevent disease from spreading to healthy fruits still on the canes. Because workers who handle both diseased culls nd harvestable fruits can spread fruit rot inoculum to healthy berries, one strategy is to have workers remove culls prior to each day's harvest. Discard all moldy or otherwise diseased or discolored fruits.

For fresh market sales, harvest only those fruits meeting color, shape, and size standards. Follow-up pickers can pick the remaining fruit for processing, if desired. Raspberries are firm and cool in themorning and are easiest to pick at thattime. Begin picking as early as light allows and the dew is off the berries. Avoid harvesting during high temperatures, if possible. Also avoid harvesting wet fruit, which rots quickly. Before entering the field, each picker should receive cards marked with his or her name. When a flat is filled, the worker places a card in the flat to identify whopicked it and to receive credit for picking those berries. Bar-coded cards and computer scanners often are used, allowing rapid and accurate tallies of how much fruit each picker has harvested.

Take the time to train pickers before they begin harvesting. Instruct pickers to remove raspberries by grasping the berries lightly between the thumb and two forefingers and using a twisting motion, rather than a pull or jerk. Pick with hands together and palms up to catch falling berries.
Avoid squeezing the berries by picking too many before transferring the fruit to the picking container.

Work from the outsides of the canes inward and avoid damaging remaining fruits. In the past, raspberries were picked into buckets attached to pickers' belts and later poured into flats for sale. Today, most fresh fruit is harvested directly into half-pint containers for sale to consumers.

Wooden or cardboard half-pint basketshave largely been replaced by clear plasticclamshell containers. Pickers are responsible for harvesting only market-quality berries and filling the picking containers to the correct level. Provide check stations in the fields so that pickers do not have to carry filled flats long distances. Standard flats hold 12 half-pint baskets or clamshells. The flats can be supported on specially constructed wire or wooden stands. Do not allow them to contact the ground. Keep all containers and flats as clean as possible before, during, and after harvest. Keep filled flats out of the direct sun and transport them to a refrigerated room as quickly as possible.

To ensure that consumers receive highqualityraspberries, shippers and larger growers bring all flats to a central house where they are inspected and may be weighed.

Berries from randomly selected baskets or clamshells are

poured out and inspected to ensure they meet minimum standards for size, color, shape, and other factors. If too many berries fail to meet the standards, the flats in that lot may be rejected or receive lower prices. Because every flat can be traced to a specific picker, quality problems can be quickly identified, additional training provided, or unsatisfactory workers replaced. Pickers are paid by the pound or by the flat.
In general, payment by the flatprovides better results for growers. Eitherway, an inspector should examine each flat to ensure it meets weight, cleanliness, and fruit quality standards. Each clamshell or basket must be filled to the correct depth. Inexperienced pickers often have difficulty judging ripeness, and dishonest workers have been known to place rocks in the bottoms of flats to increase weight. Being able to identify who picked each flat helps eliminate quality problems.

Sanitation concerns :

In the past, fruit pathogens were the primary concern during harvest. With recent outbreaks of E. coli and other human diseases associated with fresh and processed fruits, sanitation has taken on a new importance.

Any worker who shows signs of illness should be excluded from fruit handlingareas and from contacting anything that will come into contact with the fruit. Symptoms to watch for include open sores or wounds, vomiting, diarrhea, sore throat, coughing, sneezing, and jaundice. Animals and children are also potential sources of pathogen transmission and should, as much as possible, be excluded from fruithandling areas.

The most common source of fruit contamination is unsanitary worker conditions that lead to contamination with human

wastes. Provide workers with adequaterest facilities, including drinking water clean toilets, well-stocked hand washing units, and lunch shelters. According to the U.S. Occupational Health and Safety Administration (OSHA), 1 portable toilet must be provided for every 20 workers and must be kept within 0.25 mile of the workers at all times. The toilets must never be emptied while in the field.

One option is to equip a tractor-drawn trailer with portable toilets, sinks, hand soap, drinking water dispensers, disposable towels and cups, and waste containers. As the workers move through the fields, the trailer can be moved with them. Keep picking flats, containers, pallets, and plastic films used to wrap pallets clean and free of rodents and other animals. Keep fruit handling spaces and equipment clean and sanitize them daily using disinfectants suitable for a food-handling area.

Postharvest care :

Raspberries are among the most perishable fresh fruits. Picking during cool temperatures and shielding the harvested fruits from direct sun are the first steps in a closely controlled process to maintain high fruit quality. Prompt delivery to a processing plant is critical for machine-harvested fruit. Once picked, transport fresh-market berries rapidly to inspection rooms, as described above. For every 10 flats, forexample, a basket or clamshell typically ispulled from a flat and the berries poured onto a table for inspection.

Leave all other berries in their original baskets and flats, labeled with the grower's or broker's name and advertising information.

Except for the smallest operations, the flats are placed inside

refrigerated rooms containing rows of large, high-powered fans along one wall. Carefully stack the flats in rows in front of the fans, and cover the tops of the stacks with a clean tarp. Each flat contains vent holes in the sides and ends that allow cool air drawn from the fans to flow through and around the berry-filled containers. The goal is to lower the fruit temperature to about 32 to 340F within 2 hours of picking.
Maintain relative humidity within the refrigerated room at 85 to 95 percent, but keep free moisture on the berries or in thecontainers to a minimum. Unlike applesand some other fruits, fresh market raspberries are not washed or cooled in water (hydrocooling) after picking and before shipment to consumers. To reduce fruit rot, the berries must be kept dry. Controlled-atmosphere (CA) storage of apples has developed to the point that high fruit quality can be maintained for months after picking. Refrigeration, combined with careful manipulation of oxygen, carbon dioxide, and ethylene gas concentrations, reduces fruit respiration and prevents the apples from over ripening.

In recent years, great advances have been made in controlled-atmosphere storage of raspberries and other small fruits. Instead of controlling the atmosphere in large rooms, however, efforts are focused on individual pallets. Once the fruit is cooled to around 32 to 340F, the flats arestacked onto pallets.

The flats on the pallets are then wrapped in special, semipermeable, plastic film that allows some gasexchange between the fruit and outside air. Oxygen levels drop, and carbon dioxide concentrations increase. This atmosphere slows the fruit respiration rate and discourages decay organisms from growing, thereby increasing the raspberries.

shelf life. Maintaining cold temperatures throughout the pro-

cess, from packing shed to consumer table, is critically important in keeping fruit quality high and reducing the spread of human and fruit diseases.

Small growers who market through roadside stands or direct sales to local markets should follow as many of the procedures described above as possible. Keep fruit clean, dry, and cold.

Advantages of greenhouse production of raspberries:

• The grower is able to provide the consumer with a high quality fruit year-round that will both look good and offer excellent flavor.

• Compared to field production, greenhouse-produced berries are larger, firmer and much less prone to fruit rot.

• The grower is able to achieve a high level of quality because the fruit never becomes wet from rain or irrigation, thus greatly reducing the instance of fruit rotting infections, and the fruit can be harvested at the peak of ripeness for optimum flavor.

• The storage and shelf life of greenhouse raspberries under refrigeration is greatly increased because the fruit has been kept dry, and therefore, fruit rotting infections are much reduced.

Fruit tends to be slightly less sweet and more acid in the greenhouse, but well within the limits of acceptability.

• Varieties differ in performance and flavor; varieties that do well in the field will not necessarily perform well in the greenhouse.

• Consumers are willing to pay between $3.00 and $6.00 per half-pint for fresh fruit of superior quality, and restaurant chefs are often willing to pay a premium as well.

This production guide is intended to be a comprehensive resource for both the novice and experienced grower to use in establishing a successful and profitable enterprise growing fresh, high quality raspberries for the off-season market. Included is information on greenhouse preparation, plant selection, planting, insect and disease control, nutrient and moisture management, harvest, economics, and marketing.

Biology of the Cultivated Raspberry :

Cultivated raspberries are of two basic types: primocane and floricane fruiting. The primocane fruiting types produce fruit on the cane tips on the first year's growth, and a second crop lower down the cane in the following year. After the second year's crop, the canes will die and can be removed, as new canes will continue to grow from the perennial root system.

Floricane fruiting types produce fruit on the lateral branches that emerge from axillary buds on a second year cane. The cane will grow the first season (primocane), go through a winter dormancy period, and after the dormancy requirement has been fulfilled, the lateral buds will break and produce flowers that when pollinated will produce fruit.

Similar to the primocane fruiting types, after the floricane fruiting types have produced their crop, the canes will die and can be removed to make room for the new canes arising from the root system.

The canes typically exhibit an S-shaped growth curve, but this can be modified by the environment. First year canes grow rapidly after dormancy, but during hot conditions extension growth slows. If adequate moisture is supplied, elongation can

increase. Nodes on first-year canes form at a constant rate over time, and the variation in the growth rate of the cane leads to variation in internode length along the cane. The cane typically has short internodes at the base and tip, with long internodes in its mid-region.

Flower-bud initiation usually occurs under short days and cool temperatures, but with some varieties, initiation will occur once the cane reaches a certain height regardless of day length. If initiation occurs before the first year canes stop growing, the primocane fruiting trait occurs.

Fruiting lateral branches (laterals) elongate rapidly after bud break, and continue to extend until the terminal fruits begin to form. The flower buds on the laterals may or may not develop into fruit depending on cane vigor and weather conditions in the fall during flower bud initiation.

A vigorous cane and a mild fall results in more flowers per bud (node) and more nodes with flowers. Thirty or more flowers may be produced on a single flowering lateral. Most buds that reach a diameter of 2 mm continue to develop, set and mature fruit. Insect pollination is essential for good fruit set. In the absence of pollinators, drupelet set can be 80% lower.

Raspberry flowers produce copious quantities of nectar which attract pollinators. The stigmas may remain receptive for only about six days, so it is important to have the pollinators available in time to set the fruit.

The structure of the fully developed fruiting lateral varies depending on its position on the cane.

On untipped fruiting canes (canes that have not been pinched

or trimmed back to a given height), the laterals at the tip are short, have few nodes and bear a low yield of small fruits.

They become progressively more vigorous with higher yields over the middle two-thirds of the cane, although yield of the bottom laterals on the cane is decreased. Yields may be greatest in the mid-section or in the top section of a tipped cane, depending on the cane height.

Short canes with many nodes tend to have high yields on the laterals in the mid-region, whereas tall canes with few laterals and long internodes tend to produce high yields at the top of the cane. Increased cane diameter has been associated with increased yield. However, fruit numbers differ only slightly between thin and thick canes after they have been tipped.

Thicker canes generally have more berries per lateral but fewer laterals per cane than thinner canes. Thicker canes tend to be taller, and tend to take longer to break dormancy than thinner canes.

Bud break to flowering may take one to two months, depending on accumulated chilling and greenhouse temperature. Fruits take between 30 and 45 days to develop from flowering, depending on the cultivar and the environment.

Most of the increase in fresh weight takes place in the last 7-10 days of development. When the fruit becomes over-ripe, some of the weight is lost. The yield of fruit increases rapidly during the first few harvests to a peak, and then declines fairly slowly although the size of the peak and rate of decline vary with cultivar. Individual fruit weight remains fairly constant through the major part of the season and then drops towards the end.

Choosing a Production Type of Raspberry :

There are advantages and disadvantages for both primocane and floricane raspberries in the greenhouse. Some producers use a mixture of both types.

Primocane-fruiting :

Advantages:
- Long harvest season from the same plant
- Less movement of plants into and out of the greenhouse
- Shorter time from transplanting to first full harvest
- Simple trellis is required
- Higher density of plants

Disadvantages
- Mites and other pests build up during the long harvest season
- Yield per plant is low
- Bees must be active for months at a time

Florian fruiting

Advantages
- Short harvest season with high yields
- Easy to schedule production cycles
- Pests easier to control
- Only one beehive required per harvest
- Superior flavor and size

Disadvantages:
- requires extensive manipulation of plants and canes
- may be two years before full harvest is realized
- significant chilling is required to break dormancy
- plants require trellising
- larger plants take up more space

Preparing the Greenhouse Environment :

A greenhouse with a heat source will be required for maintaining warm temperatures of up to 70˚F (20˚C) inside while the weather is cold outside. Coolers and venting may be necessary for late spring production. Other materials needed include a clean water source with low salinity, a fertilizer injector, an irrigation system, growing media and at least 3 gal (13 L) containers. Other supplies that are optional include growing lights, a weed barrier for the greenhouse floor to suppress weeds and keep the plant containers from directly contacting the earth, and temperature and humidity gauges.

Humidity levels will vary when the greenhouse floor is gravel vs. when the floor is concrete. Concrete floors tend to absorb moisture much more and therefore may need to be sprayed with water during the day in order to maintain sufficient humidity.

The target range for the relative humidity is between 65-75%.

The greenhouse can be an excellent environment in which pests and disease organisms thrive. The greenhouse must be thoroughly cleaned before any raspberries are moved in. Remove any plant debris. In the summer, maintaining temperatures at greater than 104˚F (40˚C) and relative humidity at less than 50% for 3-4 days in a greenhouse that is completely void of plants (weeds, “pet” plants, unsold plants, stock plants, etc.) will eradicate many insects.

Plant Container Spacing :

Measure the available greenhouse space to determine how many containers can fit in rows about 2 ft. apart (0.6 m) with

a minimum of 5.5 to 6 ft (1.6 to 1.8 m) between rows for floricane fruiting varieties and 4 ft (1.25 m) for primocane varieties. Closer spacing may result in higher yields per house, but disease pressure will be greater. Remember to leave about 3 ft (1 m) to access both sides of the outside rows so the fruit can be harvested. Estimate how many containers will be needed, and decide how many extras are desired for replacements in case a few plants in the rows do not survive.

Plant Selection :

Obtaining high quality, virus-indexed planting stock is an important step in developing a successful bramble operation; poor plant material guarantees a poor planting. Plants should be ordered from a reputable source, preferably a nursery that sells plants from "certified" virus-indexed stock.

Virus-indexed plants have the best growth and productivity and will generally live longer. Field-grown nursery stock has a greater chance of being infected with disease, such as crown gall or Verticilliumwilt, than greenhouse stock straight from tissue culture, particularly if it is uncertified.

For reasons not yet understood, cultivars that are proven to be reliable producers of high quality fruit in the field do not necessarily perform similarly in the greenhouse. Some varieties that have performed well include the primocane varieties: 'Autumn Bliss', 'Autumn Britten', 'Josephine', and 'Caroline'; and floricane varieties such as: 'Cascade Delight', 'Chilliwack', 'Encore' and 'Tulameen'. In side by side tests, 'Tulameen' has proven to be an outstanding variety that consistently produces a high quality raspberry in the greenhouse and also has few insect and pathogen pests.

Plant Types:

Tissue Culture Plants

Tissue culture plugs provide the grower with a consistent stand of plants as well as certified virus-free plant material. They are grown under very strict propagation conditions of sanitation. The tissue culture plugs are grown under aseptic conditions to be free of known viruses, insect pests and soil borne pests and pathogens.

The plantlets are all clones of the same mother plant. Therefore, all plantlets will be nearly identical in performance and will fruit at approximately the same time. Tissue culture plants are grown for one season and fruited in the second season, with the largest crop in the third season.

This means there will be no fruit to harvest and sell until the second year of for floritime-fruiting varieties. To ensure an order is available to be shipped in full, contact the nursery six months to a year in advance of when planting is expected to begin.

Growth of tissue-cultured plugs is more uniform and vigorous than traditional plant material. When planting, the top of the root ball should be covered with soil media to a depth of 3⁄4 in (2 cm). Media should be pressed to ensure good contact with the root ball.

Tissue-cultured plants have never been exposed to the outdoors, and have shallow root systems that are sensitive to drought. They are also susceptible to frost damage. The con-

tainers should be irrigated immediately after transplanting. The containers can be placed outdoors for the plants to grow during the first season if danger of frost is past.

Nursery Mature or Dormant Short Canes/Bare Root

Dormant short canes are rooted canes or “handles” with one season of growth that were dug after becoming dormant in the fall. The canes are tipped, or cut, leaving 12 to 18 inches (30 to 46 cm) of cane above the roots.

The resulting shape looks like a “handle” and gives rise to the term used. The dormant cuttings are stored until spring shipping. This is the conventional transplant type for raspberries.

The use of dormant short canes may require the use of a larger growing container as the attached root mass may be too large to fit into a 3 gal (13 L) container without becoming damaged. All of the plant’s energy is stored in the roots, so it is best to retain as much of the root mass as possible and minimize damage.

An advantage of the dormant short canes is that they are not sensitive to frost in the spring, so they can be potted up and set outside in Spring with no worries.

It is imperative that the roots are not allowed to dry out prior to transplanting. Soaking the roots in a bucket of water just before and during planting will assist in rehydrating the roots, and give the roots a little head start in moisture absorption.

The canes will break bud and grow when outdoor temperatures are typically past the time frame of spring frosts, and any new growth that may be subjected to a spring frost will be hardy to the cold temperatures. A disadvantage of using dormant short canes is that the canes have spent a season in field

conditions that may or may not have introduced insect and/or disease pests to the plant.

It is impossible to guarantee that the dormant short canes will be 100% pest free, so close observation of the plants should occur to monitor for any indications of pest problems.

Establishing Container Raspberry Plants :

When establishing a new planting of container-grown raspberry plants, it is important to use a well-drained potting media rich in organic matter and at the correct pH and with sufficient nutrients. Raspberries grow best in media with a pH between 5.5 and 6.5.

Most raspberries will not grow well in media with a pH below 5.5, and iron deficiency may occur in soils with a pH above 7.0. Raspberries must receive adequate moisture during the first few weeks after planting. The containerized plants can be grown outdoors during the first growing season, so it is important to have an available water source near the plants so they will not dry out at any time.

Applying a few inches of compost to the pot surface will reduce evaporation and retain moisture. Fungus gnat problems may be reduced as well.

- **Container and Potting Medium Selection**

Many options are available for growing potted plants. Some growers use 3, 5 or 7 gallon (13, 22 or 31 L) containers, while some growers may use grow bags and insert the raspberry plants directly into a slit in a bag of peat. A three gallon con-

tainer is the smallest size recommended as it provides sufficient room for root and primocane growth, and it will also be easier for the grower to move in and out of the greenhouse as the container and its contents will weigh less than the larger containers and contents.

As with other greenhouse crops, the growing media chosen will depend on personal choice as well as research recommendations. What works for one grower, may not be the media of choice for another grower. One recipe that Cornell used was a soil-less mix containing 2 bu (70.5 L) peat, 2 bu (70.5 L) vermiculite, and 1 bu (35.25 L) sand. The sand was included to add weight to keep the containers from tipping over too easily. For the total 4 bu (141 L) media mixture, micronutrients were added including: 411 g of lime, 82 g of triple super phosphate, 82 g of calcium nitrate, and 124 g of Micromax trace elements. Slow release fertilizer also can be added to the mix. All the previously mentioned ingredients are thoroughly mixed and used as the growing medium for the tissue culture plugs. Other commercially available, premixed media such as Metromix and ProMix also have been used successfully. One batch of the media mixture should be sufficient to fill 15-20 3 gal (13 L) containers 2/3 full.

- **Location and Spacing :**

The plants can be potted up and placed outside to grow for the first season. Pest management materials are usually easier to apply outdoors in comparison to a greenhouse. Place the plants in full sun, out of the wind and on a growing bed with a weed barrier and automated drip irrigation.

A north-south orientation is preferred for better light intercep-

tion. If possible, locate the growing bed in a location near the greenhouse to minimize the distance for handling the containers when it comes time to move the plants into the greenhouse. This will minimize damage to the plants as well as the stress on the handler's back.

The growing bed should be located away from sources of insect and disease populations as on nearby apple trees, hedgerows, Taxus shrubs and areas containing many weeds that may disperse weed seeds into the containers.

Sufficient spacing between the rows of at least 8 to 10 ft (2.5 to 3.0 m) should be allowed for maximum sun exposure on the lower portions of the canes. If the plants are too close together, the lower buds will not produce fruiting laterals once they are moved into the greenhouse.

As the primocanes grow during that first season outdoors, support stakes will be necessary to keep the canes upright in the wind.

This upright stability can be achieved through relatively simple measures such as using strategically located bamboo stakes and a series of twine support lines run between the support stakes. Plastic tomato cllps also can be used to attach canes to stakes.

- **Pest Control**

During the first growing season outdoors (or in high tunnels), insects and diseases should be minimal, but weekly scouting should occur, especially to monitor for Japanese beetles, oriental beetles, and for raspberry sawfly larvae.

Oriental beetle pheromone dispensers will disrupt mating and reduce egg-laying. Other pests to watch for include spider mites, aphids, cane borers, tree crickets and root weevils. These and other pests are described in more detail in the insect and disease pest section. Detailed life cycles of insect pests can be found in the Bramble Production Guide (Pritts& Handley, 1989). Conventional pest control measures can be utilized when plants are outdoors.

Monitor the containers on a weekly basis and remove any weeds that may have started to grow in the containers. Weeds growing in the containers will be a source of competition for nutrients and moisture with the raspberry plants, as well as possible attractants for insects and disease. Keep the containers away from woody plants, as they may be a source of food for the black vine weevil, a pest that will come into the greenhouse inside the containers.

- **Moisture and Fertilization Requirements :**

The containers should be carefully monitored so they do not completely dry out in the sunny, warm months of summer. Newly potted or transplanted raspberry plants are very sensitive to drying out.

During hot, sunny, and/or windy days, the containers may need to be watered more than once a day. The plants should be fertilized with a complete soluble fertilizer solution containing 100 ppm N, either in the irrigation water or at least once a week, while the plants are growing outdoors.

This fertilizer solution can be applied via an injector system hooked up to the drip irrigation system or a siphon attachment

available through most nursery suppliers.

Late Season Care As autumn begins, cut back on watering and fertilizing the plants to reduce succulent growth that is more likely to be damaged by cold weather.

The containers will not require much watering, but do not allow the containers to completely dry out, as the temperatures begin to decrease in the autumn.

In October after leaf drop, move the pots closer together and surround them with bales of straw to protect them from cold temperatures. Root systems are more sensitive to cold temperatures than canes, and temperatures below 20˚F (-6˚C) for an extended period of time will kill roots, and then some canes, in pots that are setting on top of the ground.

In late December, move all of the containers into the greenhouse. Plants may have to be moved earlier if temperatures are forecast to fall below 20˚F (-6˚C) for several consecutive hours.

In this case, move plants into an unheated greenhouse or building until the end of December to allow the plants to fulfill their chilling requirement.

- **Chilling Requirements :**

Tulameen plants require a chilling period of about 800 hours of temperatures between 28˚F and 45˚F (-2˚C and 5˚C) in order to break dormancy. If this dormancy requirement is not met, the plants will not break bud, or only the top few laterals will grow and produce fruit.

To ensure that a sufficient number of chilling hours has been

achieved, plants can be moved into a cooler (that does not contain other fruit that can produce ethylene gas) for 8 weeks prior to moving them into a warm greenhouse.

If natural chilling is relied upon and autumn temperatures are mild, then chilling may not occur until later than desired. Buds on thicker canes and buds lower on the cane also have a longer chilling requirement (1000 hours) than buds on thin canes or near the top of canes.

If the greenhouse is vacant, the containers can be moved directly into the greenhouse prior to receiving sufficient chilling as long as it is possible to maintain temperatures in the greenhouse below 45˚F (5˚C).

Even on cool sunny days in autumn, the temperatures in a greenhouse can quickly rise well above the 45˚F (5˚C) mark, and this will be detrimental to the mandatory chilling period for the canes.

It may be necessary to closely monitor the temperatures inside the greenhouse at this time and open vents, doors or and use fans to ensure the temperature does not rise above 45˚F (5˚C) for too long on sunny autumn days.

Alternatively, plants can be moved into a cooler after midsummer to complete their chilling requirement and begin their fruiting cycle earlier than nature would allow.

The plants can be moved into the coolers with their leaves intact as early as August, and after the chilling requirement has been fulfilled, moved into the greenhouse where the plants will break bud, grow their laterals, flower and fruit.

Moving potted plants into the coolers and greenhouse is an

extremely labor-intensive operation.

Consider how this might be accomplished most efficiently. Some growers have built a simple support system on a pallet, and use a forklift to move several plants at a time.

Harvesting,Handling,andTransporting Fresh Fruit :

Raspberries are a very perishable commodity, but steps can be taken to give them sufficient shelf life for marketing and consumption. By using proper management practices, many problems that can lead to unmarketable fruit can be avoided. Providing proper trellising and pruning will allow air and light movement through the canopy, which will discourage decay and disease organisms.

Use drip irrigation to keep the fruit dry. This greatly reduces the amount of fungal infection on the fruit. Proper fertilization will keep plants from becoming stressed thus maintaining maximum fruit shelf life.

Keeping insect pests at low levels will be less stressful to the plants and will also keep insect feeding on the fruit to a minimum.

Just as important is the careful handling of the plants when moving them in and out of the greenhouse. Handle the plants as little as possible to minimize any damage to the canes. Even small wounds can become sites for fungal infection or cause damage to the vascular system that may not become apparent until the can be harvested slightly unripe to avoid soft, mushy berries, but flavor will be sacrificed as the berries will not continue to ripen after they have been picked.

Raspberries grown outdoors and shipped long distances tend to have very short shelf life and begin to decay very quickly, whereas greenhouse grown raspberries have been held in cold storage for as long as three weeks without showing any sign of fungal decay (although they will shrivel).

The flavor intensity will decrease after less than a week, but since greenhouse grown raspberry fruit never become wet, the occurrence of fungal decay is much reduced in comparison with raspberries grown outdoors.

Since the fruit is so delicate and flavor quality decreases rather quickly, it is best to harvest and sell the fruit as quickly as possible. If access to a cold storage facility is available, placing each filled flat of harvested fruit immediately into the cooler will help maintain the high quality of fruit until delivery to a seller or market is possible. Harvest on a daily basis to maintain quality. In the first year of fruiting, each plant can produce about two half-pints (350g) of fruit. In following years, a harvest of up to as much as 20 half-pints per plant can be obtained in a two-month harvest window.

Season Extension

By utilizing some of the following suggestions, it is possible to produce high quality raspberries during different times of the year as an alternative to relying on the brief, set time frame of the standard outdoor growing and chilling regime already described.

- **Staggered Production**

If a two-month early spring production period is too short, pro-

duction can be lengthened using a variety of techniques. For floricane-fruiting varieties, several options exist.

1) Hold plants in a cooler at 40˚F (5˚C) and bring them into the greenhouse 10 – 12 weeks before fruiting is desired. By staggering the time plants are brought into the greenhouse, production can be staggered as well. Plants can be held in a cooler from winter through summer, bringing them into a warm greenhouse as late as August or September. These plants will flower very quickly and fruit by late November. Yields tend to be lower, however, since canes would have been held a long period at cold temperatures.
2) Plants can be artificially chilled by moving them into 45˚F (7˚C) coolers as early as mid-August, with the leaves intact. After 10 weeks to primocanes, essentially mimicking winter and summer. A combination of cooler and greenhouses can be managed to eliminate outdoor growing, and establish a year around production season.

Dormant raspberry canes can be stored successfully for several months in a humid cooler maintained at about 34˚F (1˚C). Inside the cooler, plants should be watered when needed to maintain soil moisture. The longer plants are stored in the cooler, the shorter will be the time between bud break and fruiting because plants respond to warmer temperatures faster with more accumulated chilling.

These techniques open the possibility of significantly lengthening the fruiting season of floricane-fruiting greenhouse raspberries. Starting production earlier than February would have several advantages for growers who use the greenhouse for spring crops, such as bedding plants.

- **Primocane-fruiting**

Primocane-fruiting raspberries are most useful for producing fruit in late fall and early winter. Primocane-fruiting varieties will continue fruiting in coolers and 8 weeks in the greenhouse, plants will produce flowers by December and fruit by late January. In experiments at Cornell, defoliation of plants prior to chilling had no effect.
3) With a cooler, one can move plants into and out of the cooler during appropriate times (depending on day length) to provide chilling in the fall in a greenhouse or high tunnel, well past the time that production would normally cease outdoors due to cold weather, if they are moved inside the greenhouse by early September. Pinching primocanes will delay flowering and fruiting, shifting the crop to late in the fall. Experimentation will be required to determine the most effective pinching height for a particular location. This practice has been successful under high plastic tunnels, as well as in greenhouses. Greenhouse growers may also have the option of holding primocane fruiting types in a cooler until late spring to delay the fall harvest. Bumble bees are used for pollination, and the fertility program is similar with 100 – 150 ppm N until fruiting, then 50 ppm N after flowering in a complete fertilizer formula.

With a small amount of chilling, most primocane-fruiting varieties will produce a sequence of new canes that will fruit about 3 months after emergence. Once fruiting occurs, primocanes can be tipped several nodes below the fruited portion to stimulate new lateral production.

This will allow raspberry fruit to be produced for a very long period of time on a single cane. However, chilling the canes will also promote bud break. With the primocane-fruiting varieties, yield per week may be less than with floricane-fruiting varieties, but the extended fruiting season for the primocane-fruiting

varieties may equal overall total yield per plant.

The extended fruiting season also means labor and maintenance costs will be higher, but having fresh raspberries available during the autumn when they are normally not available, will also allow a grower to charge a higher price for the fruit.

Marketing Greenhouse Raspberries :

Greenhouse grown raspberries can be extremely large yet flavorful. Consumers and chefs have been willing to pay between $3.00 and $6.00 per half-pint for these superb quality fruits.

How a grower intends to market their fruit, where their potential niche market is located, and how it will be advertised and serviced should be taken into account and planned out well in advance. A Cooperative Extension agent may be a good source of helpful marketing strategies.
Some marketing options include:

- Sell directly to supermarkets or co-ops
- Sell directly to chefs
- Sell at farmer's markets
- Sell alongside spring annual/perennial plant materials
- Sell to other farmers who market retail

Sell fruit in 4 to 6 oz. containers in order to preserve quality and obtain the highest possible price.

Budget Assumptions:

The following budget scenario is based on an example of growing raspberries in a 24 X 96 ft (7.32 X 29.25 m) greenhouse. Three hundred tissue culture plants were purchased for $1.20

each and planted one each in a 3 gal (13 L) container with a soilless growing media.

The containers were spaced pot-to-pot, 100 containers per row with 6 ft (1.8 m) between rows. The building materials for the trellis support system were purchased at a local hardware supplier, and the irrigation materials were ordered from a greenhouse supply company.

A total of 41 hours of labor at $8.00/hr were added to the start-up costs including planting the tissue culture plugs, setting up the containers and assembling the trellis and irrigation systems.

The production costs for the five month growing period in the greenhouse includes the total fertilization costs, the pest management supplies, two bumble bee hives for the pollination, and a greenhouse space charge of $0.10/ft2 per month for five months. Harvesting costs include paying the picker $0.50 per half-pint piece work, and $0.10 for the cost of each half-pint container.

The yields and profitability are listed for three years (a total of four years including the planting year) realizing no yield in the planting year, 2 half-pints per plant in the first fruiting year, and 16 half-pints per plant the following years. Each half-pint of fruit received a price of $3.00.

Budget for Floricane-type raspberries

I. Start-up costs		
Planting	$1,260	
300 plants	($1,20 per plant x 300 = $360)	
300 pots (3 gallon)	($1.50 per pot x 300 = $450)	
Pro-Mix	($150 per pot x 300 = $450)	
Trellis	$1200	
Wood - screws - wires - ties		
Irrigation	$850	
Tubes - clamps - connectors		
Labor	$320	
Build trellises - planting (40 hrs)		
TOTAL	$3,630	
II. Annual production costs (mid December - mid May) Year 1 Year 2+		
Start-up costs	$3-630	
Fertilizer per pot	$400	$400
Pest management (predators - stylet oil - sticky cards)	$1200	$1200
Bee hives (2 $125 each)	$250	$250

Greenhouse costs $010 per sq ft.per month 5 months	$1,150	$1,150
Labor	$896	$1,056
TOTAL	$7,526	$4,056

Labor breakdown Year 1 Year 2			
Set out-doors	12 hrs	16 hrs	
Move plants into house	8 hrs	8 hrs	
Trellising	(8 hrs-twice)	16 hrs	16 hrs
Irrigation set-up	(8 hrs-twice)	16 hrs	16 hrs
Scout/Bicontrol (2 hrs wk)	40 hrs	40 hrs	
Primocane management	8 hrs	24 hrs	
Move plants outside	8 hrs	8 hrs	
Remove trellis and irrigation	4 hrs	4 hrs	
TOTAL	112 hrs	132 hrs	

III. Harvest costs

$0.50 per half-pint piece work

$0.10 per half-pint for containers

IV. Yields and profitability

(Yields per plant: 2 half-pints {Year 1}, 16 half-pints {Year 2}

Price received: $3.00/half-pint)

Expenses

Year	Yield	income	Harvesting	Production	Total Profit
Planting year	0	0	0	$7, 526	($7,526)
Year 1	600	$1,800	$360	$7,526	($2,616)
Year 2	4,800	$14,400	$2,880	$4,056	$7,464
Year 3	4,800	$14,400	$2,880	$4,056	$7,464
TOTAL	10,200	$30,600	$6,120	$19,694	$4,786

Reference :

Greenhouse Raspberry Production Guide

(Publication 23

Author: Kurt Koester and Marvin Pritts, 2003

https://catalog.extension.oregonstate.edu/pnw598

Commercial Red Raspberry Production, PNW 598

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