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Commercial Red Raspberry Production

in the Pacific Northwest



Acknowledgments

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Chapter 1

Commercial Red Raspberry Production



History

Raspberries have been used for millennia for food and medicine. Cato first mentioned them in pre-Christian texts, and Pliny the Elder, in about 45 A.D., wrote of the “Ida fruits” that were harvested from the slopes of Mount Ida in Greece. Raspberries were not cultivated at that time, but were collected from the wild, primarily for medicinal use.

By the 4th century A.D., the Romans had begun cultivating raspberries, and raspberry seeds have been found at the sites of Roman forts in Britain. The name “Ida” persisted and was used by the taxonomist Linnaeus to name the European red raspberry, *Rubus idaeus*. Little more was written about raspberries until the 1500s, when gardeners in Britain slowly began adopting the fruits. By the mid 1600s, raspberries had become popular in London markets.

As the fruits became more popular, gardeners began selecting and naming superior plants that developed from

chance seedlings. Tradescant’s catalog in 1656 mentioned four cultivated varieties, including a dark-fruited selection. In 1780, Richard Weston described a “twice-bearing kind,” which later would be called an everbearer, fall-bearer, primocane-bearer, or primocane-fruiter. In 1829, George Johnston’s *History of English Gardening* listed 23 cultivated raspberry varieties. Named raspberry varieties were first sold in North America by a New York nursery in 1771.

Although the fruits were undoubtedly popular for food, medicinal uses remained important. Raspberry leaf tea is an ancient, but still popular, herbal infusion. Modern research has shown that a water-soluble extract from raspberry leaves relaxes the uterine muscles. Mixtures of raspberry flowers and honey also were used as eye ointments and for treating “weak stomachs.”

Despite this long history of medicinal and food use, development of raspberry cultivars (cultivated varieties) has lagged

behind other fruits. Not until the early 1900s did researchers begin making controlled crosses, first in North America and later in Europe. “Latham” was one of the earliest cultivars developed using controlled crosses; it was released by the Minnesota Fruit Breeding Farm in 1914.

World and Pacific Northwest production

As raspberry cultivars improved, popularity of the fruits increased. Today, raspberry breeding and commercial cultivation occur in many parts of the world (Table 1). Commercial red raspberry production has proven especially popular and successful in western Oregon and Washington (Table 2), where most of the production goes for processed fruit. Red raspberries are also a popular crop throughout Idaho and eastern Oregon and Washington, where they are grown on small acreages and sold mostly through local fresh markets or used by small-scale processors for high-value, niche products.

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 *Rubus idaeus* and North American forms as *R. strigosus*. Both are diploid, intercross readily to produce fertile hybrids, and generally are considered subspecies of *R. idaeus* L. Other diploid and tetraploid red-fruited raspberry species and subspecies also exist.

While *R. idaeus* and *R. strigosus* types interbreed freely, they exhibit distinctive differences. *Rubus idaeus* berries have

Table 1. United States and European raspberry production.¹

	Acreage harvested (acres)			Yield per acre (pounds)			Total production (tons)		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
United States	6,718	10,991	15,544	3,926	4,730	7,249	13,224	26,062	56,484
Europe (total)	43,825	113,973	112,221	—	—	—	130,899	202,674	203,760
Bulgaria	8,205	4,555	3,211	1,569	2,010	2,053	6,454	4,590	3,306
France	2,964	3,208	3,609	5,117	4,386	5,326	7,604	7,055	9,635
Germany	—	12,844	14,573	—	4,662	5,084	22,704	30,020	37,137
Hungary	—	16,673	13,585	—	3,587	3,204	20,420	29,983	21,824
Poland	22,232	26,582	31,089	1,928	2,353	2,809	21,497	31,360	43,779
Serbia and Montenegro	—	—	33,436	—	—	3,687	—	—	61,777
Spain	—	617	1,543	—	3,560	3,560	—	1,102	2,755
U.K.	9,139	9,633	4,446	5,364	4,377	4,697	24,575	21,136	10,469

¹Total reported raspberry production, including red, black, yellow, and purple cultivars. Source: United Nations Food and Agriculture Organization (2005).

Table 2. Red raspberry production and prices in Oregon and Washington, 1980–2005.

	Acreage harvested (acres)	Yield per acre ¹ (pounds)	Production utilized (1,000 pounds)			Price (\$ per pound)	
			Fresh	Processed	Total	Fresh	Processed
Oregon							
1980	2,100	5,050	600	10,000	10,600	—	0.27
1990	4,200	5,120	500	21,000	21,500	0.88	0.32
2003	2,000	2,600	1,000	4,200	5,200	1.28	0.70
2004	1,900	3,530	1,100	5,600	6,700	1.37	0.76
2005	1,900	3,680	1,300	5,700	7,000	1.55	0.66
Washington							
1980	2,800	4,500	2,240	10,360	12,600	—	0.30
1990	4,600	5,000	1,000	22,000	23,000	0.90	0.35
2000	9,500	7,500	4,000	67,250	71,250	1.26	0.31
2003	9,200	7,300	1,400	65,800	67,200	1.67	0.52
2004	9,000	6,700	1,500	58,800	60,600	1.69	0.75
2005	9,500	7,400	1,400	68,900	70,300	1.97	0.53

¹Pounds of utilized berries per acre. Unharvested or discarded fruit is not included. Source: Oregon Agricultural Statistics Service (2005) and Washington Agricultural Statistics Service (2005).

glandless inflorescences and thimble- or conic-shape fruits. *Rubus strigosus* inflorescences 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, high-quality fruits on stout, cold-hardy canes.

Black raspberry cultivars are domesticated forms of *Rubus occidentalis*, 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. Cultural practices described in this guide apply to yellow cultivars.

Red raspberry production systems

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 alternate cropping 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.

In trials at Washington State University's Vancouver station, 'Willamette' and 'Meeker' were tested in alternate-year cropping for 6 years (three alternate-year cycles). Primocane suppression (see page 33) 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 alternate-year production may make it feasible for some growers.

Primocane-fruiting raspberries (also known as fall-bearers, everbearers, or primocane-bearers) produce relatively large 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 summer-bearing cultivars.

Cropping twice each year may reduce fall yields due to competition between the 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 the 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 floricanes 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 primocane-fruiting cultivars can be delayed by summer tipping of the primocanes to produce off-season crops from late fall through late winter.

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

Raspberries and human nutrition

Raspberries have long been valued for their medicinal and nutritional benefits. With today’s interest in natural foods and healthy diets, raspberries’ popularity remains strong. Recent research supports long-held beliefs that raspberries are a particularly healthy part of the human diet. The fruits contain little fat and are rich sources of dietary fiber, vitamin C, and potassium. They also are rich in anti-oxidant capacity and contain compounds thought to be important for vascular health and cancer prevention, including procyanidins and ellagic acid. Table 3 summarizes some of the nutritional characteristics of red raspberries.

Table 3. Composition of fresh red raspberries.

Constituent	Amount per 100 grams of fresh fruit
Water (percent) ¹	84.2 %
Calories ¹	57
Protein ¹	1.2 g
Fat ¹	0.5 g
Carbohydrate ¹	13.6 g
Fiber ²	6.5 g
Calcium ¹	22 mg
Iron ¹	0.9 mg
Magnesium ²	22 mg
Phosphorus ¹	22 mg
Potassium ¹	168 mg
Sodium ¹	1 mg
Vitamin A ¹	130 International Units
Ascorbic acid (Vitamin C) ¹	25 mg
Niacin ¹	0.9 mg
Riboflavin (Vitamin B ₂) ¹	0.09 mg
Thiamine (Vitamin B ₁) ¹	0.03 mg
Total anthocyanins ³	
(cyanidin 3-glucoside equivalent)	65 mg
Total phenolics ³ (gallic acid equivalent)	517 mg
Antioxidant capacity ¹	
(ORAC, Trolox equivalent)	2,400 µmol

¹B.K. Watt and A.L. Merrill. 1963. *Composition of Foods*. USDA Agricultural Handbook 8.

²USDA. 2005. National Nutrient Database for Standard Reference, Release 17.

³L. Wada and B. Ou. 2002. Antioxidant activity and phenolics content of Oregon caneberrries. *J. Agric. Food Chem.* 50:3495–3500.

Chapter 2

The Red Raspberry Plant



Raspberries live for many years. Although the canes are biennial 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.

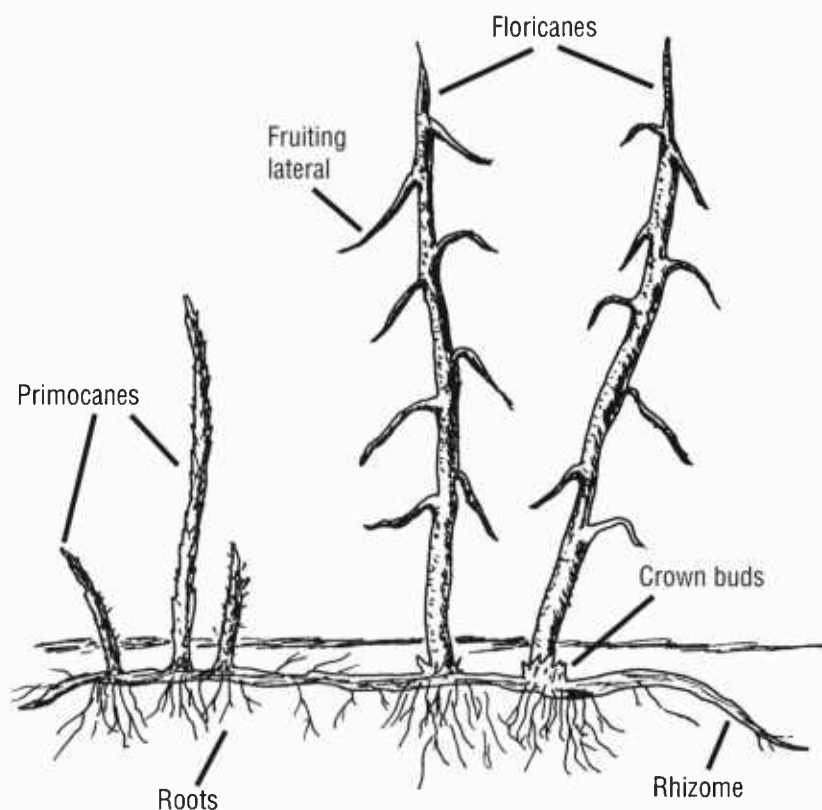


Figure 1. A raspberry plant during early summer showing newly formed primocanes and floricanes formed during the preceding growing season. The leaves and fruits have been removed to show the canes and fruiting laterals more clearly.

Roots

Raspberries have an extensive root system consisting of many fibrous, small-diameter 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 was found in the top 2 feet of soil.

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 at the florican base in a section called the crown (the perennial base of the plant) or from 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 height more slowly until cold fall weather limits their 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 florican.

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 summer-bearing 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 again during 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 45°F, 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 45°F are ideal for chilling, although chilling is reported to occur in raspberries at 28°F. 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, non-lethal, 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," page 32) 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.

Floricanes 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, floricanes 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 floricanes removal until fall, rather than removing canes immediately after harvest, unless earlier removal is desirable for disease management (see “Removing spent floricanes,” page 31).

Flowers and fruit

Red raspberry flowers have five green sepals at the base and five white petals. Many stamens (male pollen-producing parts) are arranged around a central, white receptacle containing many pistils (female fruit-producing parts). The receptacle is called a torus.

Technically speaking, a raspberry fruit is not a berry. A berry contains several to many seeds lying together within the pulp (blueberries and grapes, for example). A drupe, in contrast, is a fruit containing a single seed or pit (for example, cherries and plums). Raspberries are aggregate fruits made up of many drupelets, each of which contains a single seed and remains firm and intact during harvest. For convenience, raspberry fruits are referred to as berries throughout this guide.

Raspberry drupelets are arranged spirally around a receptacle. When picked, the raspberry separates from the receptacle, producing a hollow, thimble-shape fruit. How easily the fruits slip from the receptacle depends on the cultivar.

Raspberry fruits require about 30 to 35 days to mature after pollination. The fruits increase in size at a fairly constant rate until about 4 to 5 days before maturity. During this final stage of ripening, berries rapidly increase in size.

To attain maximum productivity, flavor, and sweetness, raspberries must reach full maturity and full size before harvest. Fruit

firmness, however, decreases during the later stages of fruit maturation. Fruit firmness is also cultivar-dependent. Particularly for fresh fruits destined for shipment to distant markets, raspberries may be harvested mature, but not fully ripe, when they are still firm enough to ship well.

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 regulators—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 bud

initiation 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 environmental 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 60°F 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 increases the percentage of bud break on the remaining canes and maintains yields in ‘Meeker.’

Chapter 3

Cultivar Selection



Selecting appropriate cultivars is critical to successful raspberry production. The Pacific Northwest is home to an incredibly diverse range of topography and climates, from USDA plant hardiness zone 9 on southwestern Oregon's mild coast to zone 5 in many of Idaho's fruit-growing regions. Cultivars adapted to one region may perform poorly or fail to survive in another.

When choosing cultivars, particularly for colder sites in and east of the Cascade Mountains, carefully consider cold hardiness. Study long-term climate records for your immediate area to determine how much cold hardiness the crop will need and during what times of the year cold hardiness will be required. Select cultivars that match those requirements. Generally, cultivars that enter dormancy early and come out of it late are the most reliable in cold climates and most resistant to late-winter or early-spring freezing injury.

Cold hardiness, however, is not the only factor to consider. 'Boyne,' for example,

is considered to be among the most cold-hardy cultivars. Inferior flavor and other undesirable fruit qualities, however, make it a poor commercial selection. 'Killarney,' a sibling of 'Boyne,' and many other cultivars have been tested in Idaho and produced commercially acceptable fruits following temperatures of -24 to -30°F.

Disease resistance is another important consideration. Some cultivars are extremely susceptible to *Phytophthora* root rot, for example, and can be especially difficult and expensive to produce.

Marketing is another factor to consider. Some cultivars are best suited to fresh markets, and some are poorly suited for commercial production. Fruit processors typically accept only certain cultivars. Before selecting cultivars, identify primary and secondary markets and the standards crops must meet.

Finally, some raspberry cultivars are machine harvestable, while others must be picked by hand, an expensive and labor-intensive process. Cultivars that are suited

to machine harvest generally have flexible, medium-length fruiting laterals. Fruit borne on short or long laterals does not separate from the receptacles easily during machine harvesting, and brittle laterals can break before the fruit separates. Cultivars suited for machine harvest also produce fruits that slip easily from the receptacles.

Many raspberry cultivars have been named and released. Some older cultivars are still popular with commercial growers, while others have been replaced by newer, better-performing, or more marketable varieties. The following lists provide guidance in selecting cultivars suited to your site, market, and production practices. Unless specifically noted, all cultivars are susceptible to raspberry bushy dwarf virus (RBDV).

Summer-bearing red raspberries for western Oregon and Washington

‘Cascade Bounty’ is a new release from the Washington breeding program, and there is limited information about its responses to a range of growing conditions and production practices. It is extremely productive, producing large quantities of medium-size, bright-colored, tart fruit. The harvest season is similar to ‘Meeker.’ In field and greenhouse tests, ‘Cascade Bounty’ has been extremely tolerant to *Phytophthora* root rot. ‘Cascade Bounty’ seems to be machine harvestable, although machine-harvested fruit may not be suitable for individually quick frozen (IQF) production. Although it has not been tested for winter hardiness, based on its parents, ‘Cascade Bounty’ may be very winter hardy.

‘Cascade Dawn’ is a new release from the Washington breeding program, and there is limited information on its

responses to different growing conditions. It produces large, medium-red to dark, early-season fruit with a harvest season similar to that of ‘Willamette’ and ‘Malahat.’ Fruit is relatively low in sugar and acidity, resulting in an excellent flavored, well-balanced, mild fruit. The fruit does not release readily until fully ripe, so ‘Cascade Dawn’ is recommended for local fresh market uses. ‘Cascade Dawn’ exhibits some field tolerance to *Phytophthora* root rot. Although it is not as root-rot-tolerant as ‘Cascade Delight,’ it is much more tolerant than ‘Willamette’ and ‘Malahat,’ other early-season cultivars. It has not tested positive to RBDV and may be immune.

‘Cascade Delight’ is a new release from the Washington breeding program, and there is limited information on its range of responses to different growing conditions. It produces large, medium-red fruit with excellent flavor. The fruit is larger and firmer than ‘Tulameen’ and ripens at about the same time. ‘Cascade Delight’ fruit is best suited to fresh uses. In some growing conditions, ‘Cascade Delight’ may be more susceptible to fruit rot than other cultivars. During 2005 in western Oregon, individual drupelets appeared more susceptible to *Botrytis* infection than those on other cultivars. In tests on sites heavily infested with *Phytophthora*, ‘Cascade Delight’ did not show any symptoms of root rot. Unless fertility is controlled, plants can become very large, with large amounts of foliage and long laterals that can break under their own weight. The long fruiting laterals are subject to breakage during machine harvesting, so ‘Cascade Delight’ is recommended only for hand harvesting.

‘Chemainus’ is a new release from the British Columbia breeding program, and there is limited information on its range of

responses to different growing conditions. It produces medium-size, bright red, firm fruit with good flavor. The fruit ripens in midseason and is suitable for processing and fresh market uses. It is well adapted to machine harvesting and IQF.

‘Coho’ is a newer release from the Oregon breeding program, and there is limited information on its range of responses to different growing conditions. It produces large, medium-colored fruit with good flavor. The fruit ripens late in the season, after ‘Meeker.’ ‘Coho’ machine harvests well, and the machine-harvested fruit can be used for IQF berries. The fruit also is suited to fresh use or freezing. ‘Coho’ is susceptible to root rot and, reportedly, crown gall.

‘Cowichan’ is a new release from the British Columbia breeding program, and there is limited information on its range of responses to different growing conditions. It produces medium to large, light-colored fruit with acceptable flavor. The fruit ripens mid- to late season and is suitable for processing and fresh markets, although softness may limit its use. It is adapted to machine harvesting. On some sites, ‘Cowichan’ seems to be susceptible to root rot. It has not tested positive for RBDV and may be immune. The plants are vigorous, establish well, and produce an abundance of new canes each year.

‘Esquimalt’ is a new release from the British Columbia breeding program, and there is limited information on its range of responses to different growing conditions. It produces very large, light-colored, late-season fruit. In some years, the skin of the fruit is somewhat thin, causing packaged fruit to “bleed” during shipping. ‘Esquimalt’ is best suited to hand harvesting for fresh uses. It is very susceptible to root rot.

‘Malahat’ produces large, firm, light-colored fruit with acceptable flavor. On

well-drained sites, it can be high yielding, but it is very susceptible to root rot. The fruit ripens early in the season, 1 week earlier than ‘Meeker’ and slightly earlier than ‘Willamette.’ The postharvest shelf life is good. ‘Malahat’ can be machine harvested, but the fruit is best suited to hand harvesting for the fresh market.

‘Meeker’ is the most widely grown raspberry in the Pacific Northwest, making up approximately 70 percent of commercial plant sales. It has medium to large fruit, medium-red color, excellent flavor, and is higher yielding than ‘Willamette.’ The fruit ripens mid- to late season, is suitable for freezing, and fair for canning and preserves. Once the plant is established, it shows a slight tolerance to root rot. Although suitable to machine harvesting, the long fruiting laterals may break.

‘Qualicum’ produces large, firm, medium- to light-red fruit with good flavor. The fruit ripens mid- to late season and is suitable for fresh and some processing uses. Unless fertility is controlled, plants can become very large, with large amounts of foliage. Because of its vigor, it can be difficult to machine harvest. ‘Qualicum’ has good winter hardiness, but it is very susceptible to root rot.

‘Tulameen’ produces large, attractive, glossy, medium-red fruit with excellent flavor. It has a long fruiting season with a midpoint of harvest similar to that of ‘Meeker.’ It is susceptible to root rot. The postharvest shelf life is good, but the fruits reportedly are not well adapted to shipping long distances. ‘Tulameen’ can be machine harvested, but its fruits are best suited to hand harvesting for the fresh market.

‘Willamette’ has medium-size, dark red fruit with good flavor. ‘Willamette’ plants usually are smaller than those of most cultivars. The fruit ripens early in the season, 1 week earlier than ‘Meeker.’ ‘Willamette’

is susceptible to root rot, but immune to RBDV. It is less cold hardy than 'Meeker.' 'Willamette' machine harvests very well, but yields are lower than those of most other cultivars. The fruit is well suited for canning and juice, but the dark color is less desirable for IQF use.

Summer-bearing red raspberries for locations in and east of the Cascade Mountains

Growing regions in and east of the Cascade Mountains are significantly colder and have shorter, cooler growing seasons than those in western Oregon and Washington. Adaptability to cold winter temperatures and widely fluctuating temperatures in late winter and early spring is an important characteristic on cold, short-season sites. Because of greater climatic variability and the emphasis on local, fresh markets, cultivar popularity differs greatly from one region to another. Most of these cultivars are better adapted to hand than machine harvest.

'**Algonquin**' is a midseason, cold-hardy variety that produces medium to large fruit with excellent flavor. In south-central Idaho trials, the fruit tended to be smaller than that of other cultivars. The fruit is suitable for fresh and processing uses. It is moderately resistant to *Phytophthora* root rot.

'**Festival**' produces midseason berries that are firm, medium-size, and have good quality. The flavor is mild and lacks sweetness. The berries are suitable for fresh or processing uses. 'Festival' is cold hardy and adapts to a range of climatic conditions. It reportedly is immune to raspberry mosaic virus, tolerant of spur blight, and moderately resistant to *Phytophthora* root rot.

'**Killarney**' produces dark red, medium-size, firm fruit with fair to good flavor. The berries are suitable for fresh use, but not for processing. The canes are spiny, medium-size, sturdy, and very cold hardy. 'Killarney' is among the most vigorous and reliable cultivars in northern Idaho trials. It is moderately resistant to *Phytophthora* root rot.

'**Nordic**' is cold hardy, shows some resistance to the aphid vector of raspberry mosaic virus, and is moderately resistant to *Phytophthora* root rot. A light fall crop of about 1,000 lb per acre is borne on the primocanes in mid-September but often is lost to fall frosts in short-season areas. Nordic is best grown as a summer-bearing crop in short-season areas, where it has proven very productive. The fruit is excellent for freezing.

'**Nova**' is a cold-hardy, early-season cultivar that performed very well in south-central Idaho trials. The plants establish quickly and bear large, early yields. The berries are small to medium size, moderately firm, and have a tart flavor.

'**Qualicum**' was described under western Oregon and Washington cultivars. It performed reasonably well in south-central Idaho trials, although its root rot susceptibility could create challenges for commercial growers.

'**Reveille**' is an early-season cultivar that is productive, vigorous, upright, and suckers freely. The fruit is large, bright red, somewhat soft, and has a good, tart flavor. This cultivar was developed for U-pick and market garden production. 'Reveille' is cold hardy and tolerates fluctuating spring temperatures. It is moderately resistant to *Phytophthora* root rot.

'**Skeena**' berries are medium to large, bright red, and fairly firm. The fruit is sweet, flavorful, and suitable for fresh or processing uses. The canes are vigorous

and productive, but are very susceptible to *Phytophthora* root rot. Although popular for its flavor, 'Skeena' can be difficult to grow over the long term because of its root rot susceptibility, and it is questionable for commercial production. It is listed here only because of its past popularity.

'**Souris**' is cold hardy and ripens early in the season. The berries are medium size, have excellent flavor, and are suitable for fresh or processing uses. It is moderately resistant to *Phytophthora* root rot.

Primocane-fruiting raspberries

Fall frosts and fruit rot due to wet conditions limit the production of fall-bearing raspberries in cooler, short-season locations. For short-season locations, early-ripening cultivars, such as 'Summit' and 'Autumn Bliss,' are preferred.

'**Anne**' is a yellow-fruited, fall-bearing raspberry. Information on its performance in the Pacific Northwest is limited. It ripens with 'Caroline,' about 1 to 2 weeks before 'Heritage,' and produces large berries with good flavor. 'Anne' reportedly is susceptible to fruit rot and may benefit from growing under hoop houses or other protective structures.

'**Autumn Bliss**' produces large berries early in the season, with berry size decreasing as the season progresses. Berries produced later in the season may be coarse. The fruit has acceptable flavor and is medium red, but can become dark and may be soft. This cultivar is one of the earliest ripening primocane-fruiting raspberries, ripening 10 to 14 days before 'Heritage.' Because of the long fall production season, it can be very productive. 'Autumn Bliss' is used for the early-fall fresh market and is a good choice for eastern Pacific Northwest sites.

'**Autumn Britten**' has the same parents as 'Autumn Bliss' and shares many of the same characteristics. It produces large, early-season berries that are better shaped than 'Autumn Bliss,' although production may be less.

'**Caroline**' is a release from Maryland, and there is limited information on its performance in the Pacific Northwest. It produces large, attractive, midseason fruit, 7 to 19 days before 'Heritage,' and it is used for the fresh market. 'Caroline' plants are vigorous and establish well.

'**Chinook**' is a recent release from the Oregon breeding program, and there is limited information on its range of responses to different growing conditions. It has the same parents as 'Summit' and shares many of its sibling's characteristics. 'Chinook' is productive and bears early in the season, about the same time as 'Autumn Bliss.' Determining when the fruit is fully ripe for picking can be difficult. The fruit is very large, with fair flavor, and is used for the early-fall fresh market. In field tests, 'Chinook' proved tolerant to root rot. It bears a heavy fruit load close to the ground and requires trellising.

'**Dinkum**' was developed in Australia. It produces large, good-flavored fruit that can darken as the season progresses. The berries begin ripening a few days after 'Autumn Bliss' and are used for the fresh market. 'Dinkum' reportedly is susceptible to root rot.

'**Heritage**' produces medium-size, firm fruit that has good flavor. The berries begin ripening in late August or September in cool, short-season locations and, in many years, production is limited by deteriorating fall weather. 'Heritage' is used for the mid- to late-season fresh market. 'Heritage' is well-adapted to western Oregon and Washington. In and east of

the Cascade Mountains, production is best limited to the warmest, longest season locations.

‘Summit’ produces small to medium-size fruit early in the season. As the harvest progresses, the berries decrease in size and may appear coarse. Fruit size generally is smaller than that of ‘Autumn Bliss,’ and the berries ripen at about the same time. The berries are firm, have acceptable flavor, and are medium red, but they may become dark. ‘Summit’ is used

for the early-fall fresh market. In field tests, ‘Summit’ proved tolerant to root rot. It is a good primocane-bearing cultivar for cool, short-season locations.

‘Golden Summit’ is a naturally occurring sport of ‘Summit’ that produces gold-apricot colored fruit. Other plant and fruit characteristics are similar to ‘Summit.’ The color can be genetically unstable, and reversions to red fruit reportedly are common. Fruit quality does not seem to be as good as that of ‘Anne.’

Chapter 4

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 45°F are needed to meet chilling requirements. Chilling units do

not accumulate as rapidly at subfreezing temperatures or at temperatures much above 45°F.

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 25°F in southwestern Oregon to 10°F 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. See Chapter 3, “Cultivar Selection,” for cultivar descriptions.

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 excessive 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. Soil acidification is discussed in more detail in Chapter 6.

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 of serious *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 (SO₄), boron (B), and lime requirement. Soil nitrogen analyses for nitrate (NO₃) or ammonium (NH₄) may be conducted, but are less useful. Tests for salinity and other macro- and micronutrients are available, if needed. See Chapter 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 plant-parasitic 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 cost-effective.

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 cost-effective 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 $\frac{1}{4}$ inch in diameter with well-formed 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 $\frac{1}{16}$ to $\frac{3}{16}$ 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 tissue-cultured 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, tissue-cultured 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 modern 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.

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, summer-bearing raspberries can be grown in either system. Hedgerows are common for

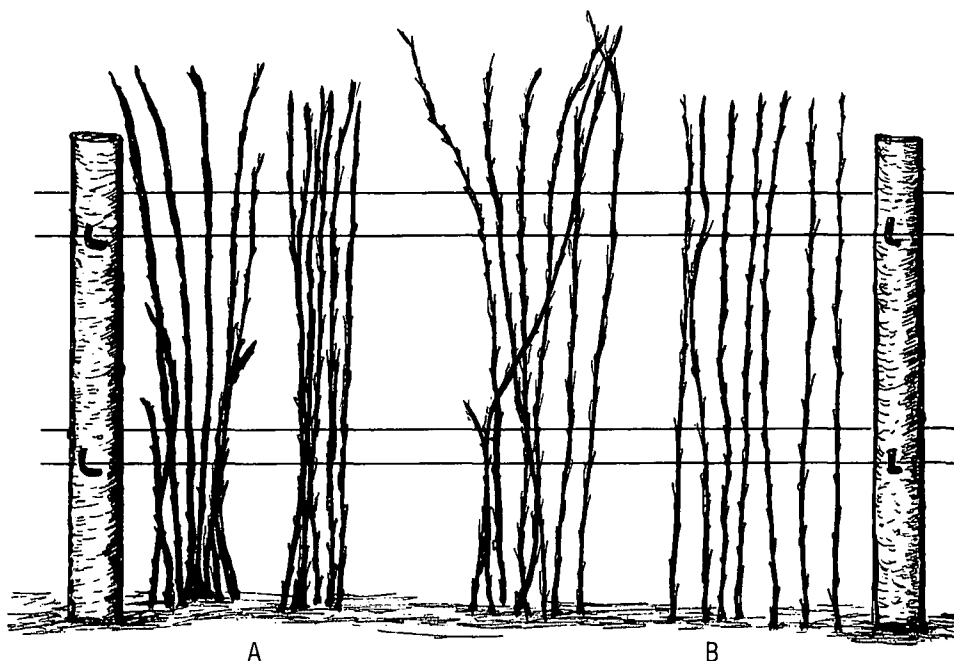


Figure 2. Typical four-wire trellis design showing unpruned and pruned winter canes for (A) hill-trained red raspberries and (B) hedgerow-trained red raspberries. The top wires usually are 5 to 6 feet above ground.

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. Primocane-fruiting raspberries typically are grown in 12- to 18-inch-wide hedgerows, whereas summer-bearing hedgerows are kept about 12 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. Training and trellising are discussed in Chapter 5.

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 2½ 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

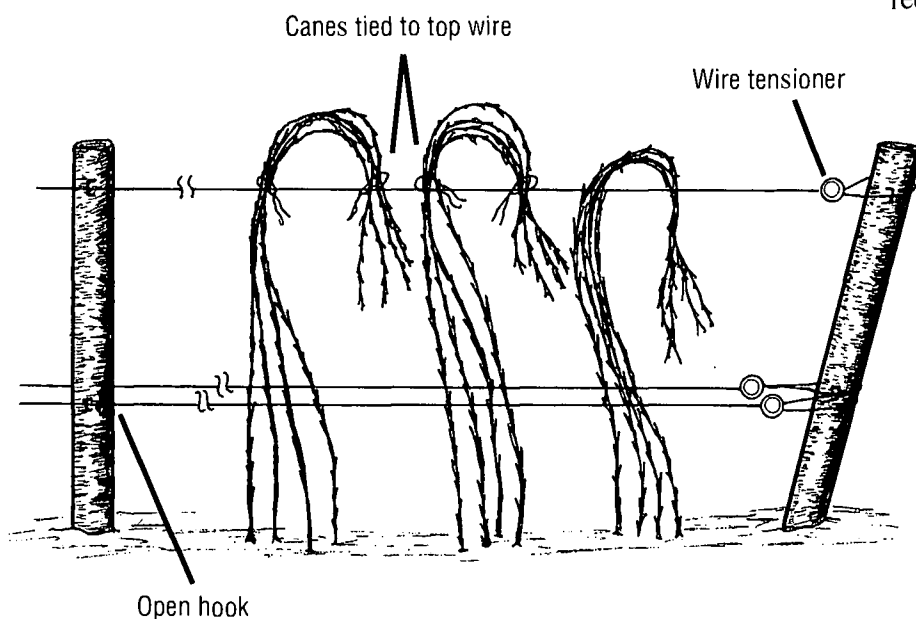


Figure 3. Typical three-wire trellis design for arc-trained red raspberries. The top wire usually is 4½ to 6 feet above ground. Wire tensioners at the ends of rows and open hooks on the poles allow the lower wires to be pulled out to catch canes and bring them into the centers of the rows.

support canes in hill systems, commercial growers utilize various trellis designs.

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 4½ 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 hill-trained 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

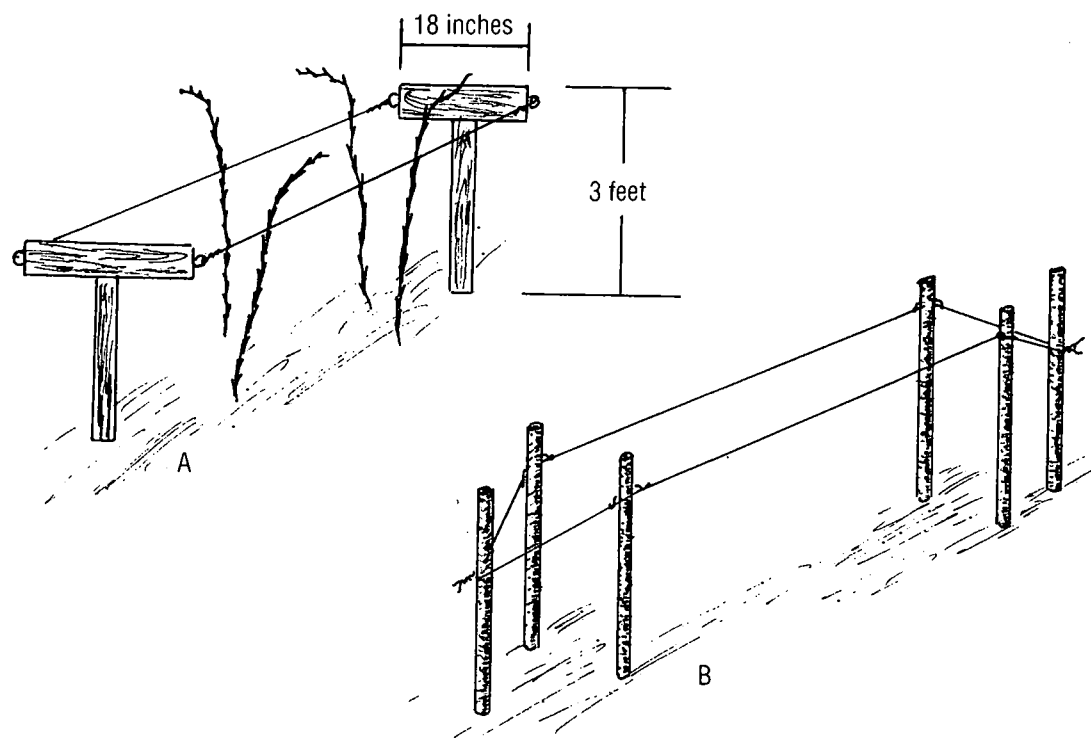


Figure 4. Typical trellis designs for primocane-fruiting raspberries.

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 crossbars 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

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 tissue-cultured plants, keep the shipping and storage times as short as possible.

Most planting stock is 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 36°F 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 $\frac{3}{4}$ 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.

Chapter 5

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 summer-bearing raspberries are grown in a hill system, the primocanes that emerge between hills are also removed.

Pruning and training

Summer-bearing raspberries

Pruning and training of summer-bearing raspberries includes floricanes 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, floricanes 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 floricanes 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 winter-damaged 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 density 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 lineal foot 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 5°F 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 portion 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 mild-climate areas. Field-grown primocane-fruiting 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. Primocane-fruiting 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 be lost.

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 decompose 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 water per 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 roots grew 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 primocane-fruited raspberry production. In New York trials, researchers found that applying straw mulch to newly planted, tissue-cultured, primocane-fruited 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-pollinating 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 domestic 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 55°F, 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*, PNW 591.

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.

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.

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 decisions. 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, water-filled 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-to-operate 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

Evaporation pan method 1: Scheduling irrigation based on soil type

Soils vary in the amounts of water they have available for plant use. Silt loams contain about 9.6 inches of available water in the top 4 feet of soil. Sandy loams can hold about 8.1 inches of available water in the same amount of soil. With this information, one can determine irrigation needs.

In Example 1, the soil has a moisture-holding capacity of 2 acre-inches per foot of depth, making a total of 8 inches for the 4-foot rooting depth. Allow 65 percent removal of the water (5.2 inches) before irrigating. Raspberries use 1 inch of irrigation water for each inch of water lost from the evaporation pan. Therefore, 5.2 inches of water must be applied to bring the soil back to saturation or field capacity.

The distribution patterns of sprinklers are not uniform; a conservative estimate is 75 percent coverage. Applying this efficiency factor to an irrigation system rated at 0.33 inch water per hour shows that 21 hours of irrigation are needed to apply 5.2 inches of water.

Water use between irrigations

Effective root depth	4 feet
Available water per foot of soil depth	2 inches
Total water available (4 x 2)	8 inches
Use 65% of water before irrigating (0.65 x 8)	5.2 inches
Evaporation equivalent (5.2 x 1.0)	5.2 inches

Irrigation

Sprinkler application rate	0.33 inch per hour
Sprinkler efficiency or coverage	75%
Length of irrigation needed	$5.2 \div (0.33 \times 0.75) = 21$ hours

Evaporation pan method 2: Determining length of irrigation based on an irrigation schedule

Some growers irrigate on a regular schedule. Evaporation pan data can be used to tell how long to irrigate at each application.

Time between irrigations	10 days
Evaporation measured during the 10-day period	2.56 inches
Inches of irrigation water needed (2.56×1.0)	2.56 inches
Sprinkler application rate	0.33 inch per hour
Sprinkler efficiency or coverage	75%
Length of irrigation needed	$2.56 \div (0.33 \times 0.75) = 10.3$ hours

Evaporation pan method 3: Deciding when to irrigate with a fixed length of irrigation

Desired length of set	12 hours
Application rate	0.33 inch per hour
Amount applied in 12 hours (12×0.33)	4 inches
Usable application (0.75×4)	3 inches
Amount of soil moisture loss to allow between irrigations	3 inches

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 1½- to 2½-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

Table 4. Common annual weeds in Pacific Northwest red raspberry fields.

Mostly west of the Cascades	Mostly east of the Cascades	Throughout the region
Winter annuals		
Little bittercress (shotweed)	Downy brome (cheatgrass)	Henbit
Purple deadnettle	Field pennycress	Common chickweed
		Shepherd's-purse
		Ryegrass
		Annual bluegrass
Summer annuals		
Pale smartweed	Green foxtail	Pineappleweed
Ladysthumb	Tumble mustard	Redroot pigweed
Hedgemustard	Kochia	Common lambsquarters
Pearlwort	Mayweed chamomile (dog fennel)	Barnyardgrass
Hawksbeard	Fiddleneck tarweed	Wild mustard (several species)
Wild radish	Russian thistle (tumbleweed)	Purslane
	Catchweed	Wild buckwheat
	Flixweed	Prickly lettuce
	Blue lettuce	Annual sowthistle

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.

Table 5. Common biennial weeds in Pacific Northwest red raspberry fields.

Mostly west of the Cascades	Mostly east of the Cascades	Throughout the region
Tansy ragwort	Salsify Sweet clover	Bull thistle Wild carrot Burdock Common mullein

Table 6. Common perennial weeds in Pacific Northwest red raspberry fields.

Mostly west of the Cascades	Mostly east of the Cascades	Throughout the region
Common catsear Broadleaf dock Hedge bindweed Stinging nettle Tall fescue Velvetgrass Creeping bentgrass Fireweed Blackberry Creeping buttercup	Field bindweed Chicory Smooth brome	Common dandelion Canada thistle Curly dock Red sorrel White clover Horsetail (Equisetum) Yellow nutsedge Quackgrass Orchardgrass Timothy St. Johnswort Yarrow Common tansy Common mallow Plantain (broadleaf and buckhorn) Reed canarygrass

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

Use herbicides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the herbicide label—even if you've used the herbicide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply herbicides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from herbicide use.

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 non-selective 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.

Weeder geese

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.

Cover crops and 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 pre- and 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 broad-leaf crops in the alleys reduce weed seed germination and can capture soil nutrients that might otherwise be lost to runoff or

Table 7. Common cover crops and their characteristics.

Common name	Seeding rate (lb/acre)	Establishment rate	Annual nitrogen requirement (lb/acre)
Annual cover crops			
Barley (spring)	120	fast	30–50
Barley (winter)	120	medium–fast	30–50
Buckwheat (common)	35–60	medium–fast	10–20
Buckwheat (tartary)	25	medium–fast	10–20
Oats (spring or winter)	120	medium–fast	30–50
Peas (winter or spring)	120	medium–fast	by soil test
Ryegrass (annual)	30	fast	30–50
Wheat (spring)	120	medium–fast	20–50
Wheat (winter)	120	medium	30–50
Grain/Pea	80/100	fast	20–30
Perennial cover crops			
Fescue (hard)	20	slow	20
Fescue (sheep)	20	very slow	20
Fescue (tall)	25	medium	20
Perennial rye	25	fast	30
Russian wildrye	30	slow	20
Siberian crested wheatgrass	35	medium	20
Standard crested wheatgrass	25	medium	20
White clover	4	medium	0
Red clover	5	medium	0
Yellow sweet clover ¹	5	medium	0
Strawberry clover	4	medium	0
Birdsfoot trefoil	3	slow–medium	0

¹**Caution:** Yellow sweet clover contains coumarins, which can be fatal to livestock foraging on pure stands.

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.

Table 8. Weed suppression ratings for selected cover crops in western Oregon-grown red raspberries.¹

Cover crop ²	Mid-May weeds	Mid-June weeds
	Annual bluegrass Chickweed Mouse ear chickweed Groundsel Shepherd's purse	Annual bluegrass Chickweed Smartweed, pineapple weed Wild radish Wild lettuce
'Amity' oat	Good	Good–excellent
'Flora' triticale	Good–excellent	Excellent
'Stephens' wheat	Good–excellent	Good
'Wheeler' rye	Excellent	Excellent
Oat–pea mix	Fair–excellent	Good–excellent
Austrian pea ³	Fair–good	Good–excellent
Vetch ³	Poor–fair	Fair–excellent
Native vegetation control	Few weeds present	Weeds well established
Clean control	—	—

¹Excellent = 85–95% suppression; Good = 75–84% suppression; Fair = 65–74% suppression; Poor = below 64% suppression.

²Varieties change as new selections are named and released by breeders. Also, varieties suited to one area do not necessarily perform well in other locations. Extension agents/educators and seed suppliers can assist in selecting varieties.

³Weed suppression in vetch and pea was directly related to stand quality. Where stands were thick, weeds were effectively suppressed. Stands, however, generally were patchy.

Source: *Cover Crops for Weed Suppression and Biomass Production in Red Raspberries*. D. Kaufman, R. Karow, R. William, and B. Strik. Oregon State University (final report).

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.

Chapter 6

Plant Nutrition Management



This chapter addresses nutrient assessments and applications for red raspberry production in the Pacific Northwest. Fertilizer recommendations are based on spacing raspberries 2½ feet apart in rows 10 feet apart.

Red raspberry plants require chemical elements from air, water, and soil to produce vegetative growth and fruit. Low levels of nutrients in the plant can affect growth and yield. Very low nutrient supplies can lead to physiological disorders, characterized by leaf discoloration, leaf distortion, and other visible symptoms.

Mineral nutrients, such as nitrogen, phosphorus, and potassium, are added through fertilizers to supplement soil supplies. Nutrient applications influence yield, fruit quality, and fruit maturity, and they provide for sustained plant vigor.

In order to gain benefits from fertilization, crop management—from selecting certified plants to postharvest irrigation—must be appropriate and timely.

Fertilization is not a substitute for poorly timed irrigation, late harvest, or failure to control insects, diseases, rodents, or weeds. Soil properties such as low pH and/or poor drainage can limit berry yield. Increasing fertilizer rates or adding nutrients already in adequate supply will not correct these limiting factors. Fertilizer applications should be part of a complete management package.

Growers, with the assistance of local Extension agents and field representatives, should consider the nutrient needs of each field. Soil and tissue sample analyses help in determining appropriate nutrient applications. Recording weather, disease problems, and nutrient application rates and timing will help in interpreting soil and tissue analysis data. Observations of annual growth (cane number, diameter, and height, and fruiting lateral length), yield, leaf color, and fruit quality (amount of rot and drupelet set) also help in determining nutrient needs.

The goal of fertilizing any high-value crop is to supply the crop with ample nutrition in advance of demand, thereby removing nutrient limitations to yield and quality. Important considerations include the economic return from the fertilizer investment, environmental stewardship, and government regulations. A fertilizer application should produce measurable changes in plant growth or nutrient status, or otherwise benefit the crop in a measurable way. The increased fruit yield or quality produces a return on the investment.

Tissue testing

Plant tissue analyses indicate which elements the tissues contain in adequate, deficient, or excessive amounts. Routine tissue analysis can help in detecting low nutrient concentrations before visible symptoms or yield reduction occur. By analyzing dried plant tissues for their nutrient content, growers can evaluate the adequacy of some mineral nutrients. This information will help in deciding whether fertilizers are needed and, if so, how much and what kind to use. Tissue testing can be used for:

- Predicting fertilizer needs of annual crops
- Diagnosing problems
- Evaluating a fertilizer program for perennial crops

Tissue testing can be used to monitor and adjust fertilizer use during early growth stages of annual crops such as potatoes, sugar beets, or lettuce. By using a tissue test, growers can anticipate fertilizer needs for these annual crops. In contrast, using tissue test results to anticipate current-season fertilizer needs does not work well for perennial crops such as raspberries. In part, this is due to the minimal short-term effects of fertilizer on yield in perennial crops.

Changes in tissue nutrient concentrations may not be observed in perennial crops, such as red raspberries, for 1 to 2 years after fertilization. Delays in plant uptake are common, particularly when relatively immobile materials, such as phosphorus, potassium, and lime, are top-dressed. (Nitrogen deficiency symptoms, shown in Plate 5, can be corrected more rapidly.) Thus, tissue testing in producing raspberries is best used for end-of-season evaluation of a fertilizer program for the next year.

If problems such as poor cane growth or foliar discoloration appear during the growing season, a comparative tissue test can be used to check for possible nutrient deficiencies. Tissue testing to diagnose deficiencies may be done at any time during the season. However, when outside the normal late-July to early-August sampling period (see “When to sample,” below), also collect a sample from an unaffected area for comparison.

Before using tissue testing to predict or evaluate fertilizer needs, the following information is needed:

- When to sample
- How to sample (plant part, number of leaves)
- Normal or sufficient concentration range for each nutrient

These topics are discussed below.

When to sample

Collect tissue samples when nutrient concentrations are stable. Samples collected just a few days apart during periods of rapidly changing nutrient concentrations can give quite different results. Changes in nitrogen, phosphorus, and potassium concentrations in leaves of ‘Meeker’ red raspberry during the growing season are illustrated in Figure 5. Note

that tissue concentrations of nitrogen and potassium change substantially during the season but stabilize in late July and early August. Samples collected at this time should produce consistent analytical results.

Figure 5 illustrates the danger in collecting samples in late September. Foliar nitrogen concentrations decrease as plants enter dormancy, so these samples may not give an accurate picture of the situation during the preceding or following growing season.

For best results, collect raspberry tissue test samples during the stable period from late July to early August. Sampling raspberry tissue at any other time is not recommended except when samples are collected for comparative tissue testing.

How to sample

Collect samples in paper bags. Collect 50 of the most recent, fully expanded primocane leaves about 12 inches below the cane tips. Collect only one leaf per primocane. A single sample should not represent more than 5 acres nor contain leaves from more than 50 primocanes. Collect leaves that are free of disease or other damage if possible. Pick leaves so that the petiole (stem) remains with the leaf. Note: Do not mix cultivars in a tissue sample. Each sample should represent a single cultivar.

Preparing and shipping samples. Do not wash the leaf samples. Air dry samples if you cannot ship them immediately. Ship fresh samples early in the week to ensure delivery before the weekend and reduce

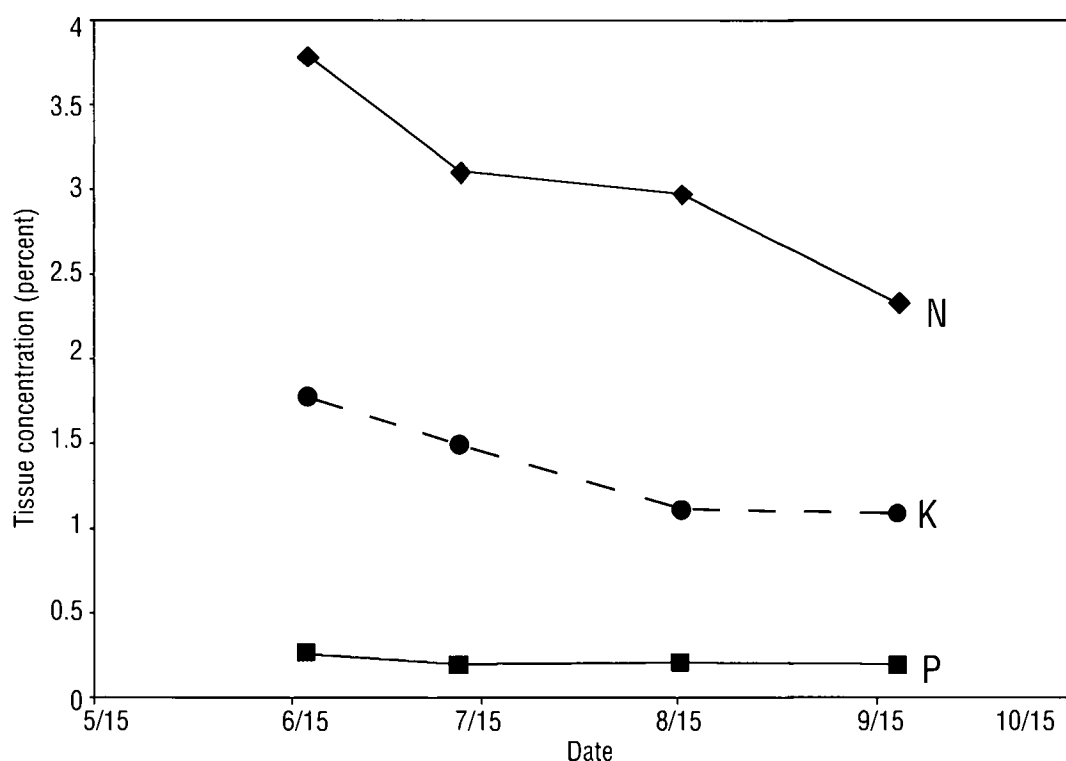


Figure 5. Seasonal changes in nitrogen (N), phosphorus (P), and potassium (K) concentrations in raspberry leaves. Data were collected from Oregon-grown 'Meeker' raspberries.

the likelihood of spoilage. Ship samples in paper bags. Do not use plastic bags or containers, as the plant materials may mold or spoil if placed in plastic.

A list of laboratories that perform tissue analyses is available in *Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis*, EM 8677. (Laboratories serving Idaho and Washington are included.) Ordering instructions are found in “For More Information” (page 97). In Idaho and Washington, contact your county Extension agent/educator to identify additional analytical laboratories.

Frequency of sampling

Annual sampling of all fields is ideal for gathering nutrient status information. Annual sampling, however, is not always necessary or financially feasible. Regardless of whether you collect samples every year, develop a plan for regular sampling.

Begin with fields that are not growing or yielding as desired. Collect samples annually from these fields until the problem is identified and/or corrected. Divide the remaining acreage into two or three blocks. Sample from one block of fields each year. This method allows sampling of one-half or one-third of the acreage each year.

Interpreting laboratory results

Compare the results from a laboratory analysis to the values described in Tables 10–12 (pages 56–58) to determine whether the crop is receiving adequate nutrition. Review cane growth and yields from the previous growing season. Choose the combination of tissue analyses and crop growth listed below that corresponds to your situation. Follow the instructions given to manage your fertilization program.

For summer-bearing red raspberries in the western Pacific Northwest, canes 7 to

9 feet high and ½ inch in diameter are desirable. Canes on primocane-fruiting cultivars grow 4 to 6 feet tall. Primocane heights are often slightly less in cooler, short-season locations.

- **Low tissue analyses and abundant cane growth.** Excessive cane growth usually is caused by an overabundance of nitrogen. Lower-than-normal tissue nutrient concentrations are common with excessive cane growth. In this situation, low tissue nutrient concentrations occur because the nutrient content of the tissue is diluted by the intensive growth. This condition should correct itself when growth returns to normal. Therefore, do not apply extra fertilizer, especially nitrogen, to correct low tissue concentrations in a situation of excessive cane growth. Below-normal nitrogen and high vigor also can occur on canes with little or no crop.
- **Low tissue analyses and weak cane growth.** If canes are weak, discolored, or stunted, apply fertilizer at rates recommended by your local Extension office.
- **Normal tissue analyses and cane growth.** If tissue analyses and growth are within the normal range, continue with the current fertilizer program.
- **Above-normal tissue analyses and weak cane growth.** If the canes are weak, discolored, or stunted, and tissue analyses are above normal, look for stress from pests, poor drainage, drought, frost, or other factors.
- **Above-normal tissue analyses and cane growth.** If tissue analyses are above normal and cane growth is adequate or above normal, reduce the amount of fertilizer applied, especially nitrogen.

Other considerations

Tissue analysis results outside the normal range cannot always be attributed to a fertilizer program. Deficient mineral nutrient concentrations in tissues can be caused by saturated or dry soils; high temperatures; frost; shade; weed, insect, or disease pressure; or herbicide injury.

Several fungicides contain plant nutrients. Because tissue samples are not washed before analysis, high copper (Cu), manganese (Mn), or zinc (Zn) may be the result of fungicide residue. High boron (B) and Zn also may occur if liquid or foliar fertilizer was used.

Soil sampling

In contrast to the use of annual tissue analyses to manage nutrient needs in raspberry production, soil analyses are most useful when obtained before planting. Collect soil samples during the summer or fall before planting to estimate amounts of nutrients, lime, and/or sulfur needed. After planting, periodic soil analyses can be helpful in diagnosing problems, such as low or high soil pH or the presence of excessive salts.

Fertilizers are commonly applied in wide bands centered on the raspberry rows. While this strategy works well from a crop production standpoint, banded applications concentrate nutrients and can complicate soil sampling. The fact that nutrient concentrations vary horizontally between the alleys and crop rows when fertilizers are banded is relatively easy to understand. Less obvious is vertical stratification of nutrient concentrations. Phosphorus and potassium are relatively immobile in the soil and tend to remain where they are placed or to migrate

slowly downward. This immobility can result in soils with decreasing phosphorus and potassium concentrations as depth increases.

Additional information about soil sampling is available in *Soil Sampling for Home Gardens and Small Acreages*, EC 628, and *Monitoring Soil Nutrients Using a Management Unit Approach*, PNW 570-E. These publications are available through Oregon State University. See “For More Information” (page 97).

Nitrogen (N)

Nitrogen requirements vary with yield, cane growth, plant age, soil type, irrigation, rainfall, and cultivar. Cane growth is an initial indicator of nitrogen sufficiency. Some raspberry cultivars are more vigorous than others and may require less nitrogen to give the desired amount of cane growth. Less nitrogen is also required in the planting year than in subsequent years.

Excess nitrogen adversely affects yield, fruit quality, and the fruit’s ability to withstand shipping. It also can promote vigorous vegetative growth. Excessive vegetative growth leads to longer, thinner primocanes with longer-than-normal internodes (distance between buds), thereby reducing yield per cane. Excess nitrogen also can increase lateral lengths on floricanes. Long laterals increase the risk of breakage during machine harvest as well as the risk of postharvest fruit diseases.

Nitrogen fertilization should be based on tissue nitrogen concentration, cane vigor, yield, and irrigation practices. Tissue nitrogen concentration from a late-July or early-August sampling should be between 2.3 and 3.0 percent.

Nitrogen for summer-bearing red raspberries

A general guide for nitrogen fertilizer needs for summer-bearing red raspberries is 30 to 50 lb N/acre in the establishment year and 50 to 80 lb N/acre in subsequent years.

Fruit firmness may be reduced if excess nitrogen is applied from late winter through early spring, as a considerable portion of early-season nitrogen fertilizer goes to the fruit. In summer-bearing red raspberries, fertilizer nitrogen that is applied early (before new primocane emergence or when primocanes are less than 6 inches tall) is taken up by the new primocanes and the fruiting laterals and fruit on the floricanes.

In contrast, when nitrogen is applied later (when green fruit is present, approximately 1 month before the first harvest), most of the fertilizer nitrogen is taken up by the primocanes and little goes to the fruit. This nitrogen will be stored in primocanes, crowns, and roots, and is important for sustaining yields from year to year. Summer-bearing red raspberries have been shown to use about 40 percent of their stored nitrogen each year.

Research has suggested that a split application of nitrogen fertilizer is best for maintaining current-season yields and acceptable primocane growth for next season's crop. Apply one-half of the nitrogen fertilizer about 1 week before primocane emergence and one-half about 1 month before the first harvest.

Nitrogen for primocane-fruiting red raspberries

Primocane-fruiting red raspberries generally require 30 to 50 lb N/acre in the establishment year. In subsequent years, apply a total of 70 to 100 lb N/acre.

Apply 25 to 40 lb N/acre about 1 week before primocane emergence and an additional 25 to 40 lb N/acre about 1 month before the first summer harvest. Apply the remaining 20 lb N/acre when the primocane blossoms appear.

How to apply

Nitrogen can be efficiently applied with phosphorus and potassium. Apply fertilizer in bands about 2 feet wide and centered on the rows. Nitrogen can be lost from surface-banded applications if the fertilizer is not washed into the soil by rain or irrigation within a few days following application.

Nitrogen fertilizer materials

Red raspberries use the nitrate (NO_3^-) form of nitrogen more readily than the ammonium (NH_4^+) form. Nitrate nitrogen is soluble in water and moves into the soil or plant rapidly, but it also leaches easily from soil. Ammonium nitrogen is less easily leached because it binds to soil particles. Because nitrate nitrogen generally is more expensive than ammonium forms, many growers apply urea or other ammoniacal sources of nitrogen.

Ammonium nitrogen is converted into the nitrate form through a process called nitrification. Soil pH is one factor controlling nitrification. Ammoniacal nitrogen is rapidly converted to nitrate in warm, moist soil with a pH above 6.0.

Different fertilizer materials are nitrified at different rates, especially at lower soil pH. For example, urea and ammonium nitrate act similarly when the soil pH is 6.0 but differently at pH 5.5. Figure 6 illustrates relative nitrification of ammonium nitrate, ammonium sulfate, and urea. Note that all nitrogen sources nitrify faster at pH 6.0 than 5.5.

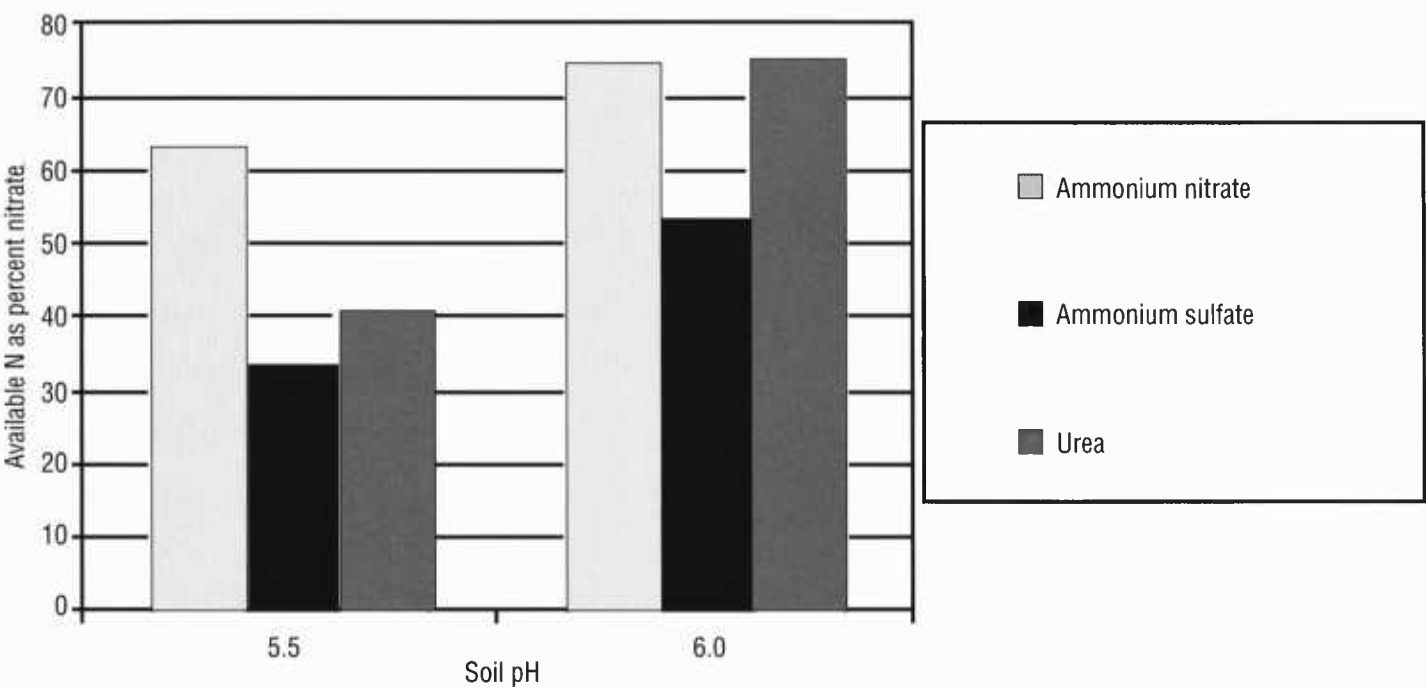


Figure 6. Relative nitrification of nitrogen fertilizers at two levels of soil pH. Results from application of 140 lb N/acre on a western Oregon farm on March 7, with sampling on April 23.

Table 9. Effects of nitrogen application rates on soil pH, SMP¹ values, and liming rates.²

	Dayton silt loam			Concord silt loam			Bashaw silty clay loam				Amity silt loam		
N rate (lb/a)	Soil pH	SMP pH	Lime (ton/a) ³	Soil pH	SMP pH	Lime (ton/a) ³	Soil pH	SMP pH	Lime (ton/a) ³		Soil pH	SMP pH	Lime (ton/a) ³
0	5.9	6.6	0	6.2	6.7	0	5.4	5.3	4.3 ⁴	6.0 ⁵	7.1	6.9	0
135	5.5	6.5	1	5.8	6.4	1.1	4.9	5.2	4.7	6.4	6.6	6.7	0
270	5.2	6.2	2	5.6	6.3	1.5	4.8	5.1	5.0	6.9	6.0	6.5	1

¹Shoemaker, McClean, and Pratt (SMP) buffer lime requirement soil assay.

²Data were collected in Oregon's southern Willamette Valley.

³Liming rates vary according to soil conditions and cultural practices. Consult a soil analytical laboratory to determine appropriate liming rates for your fields.

⁴Lime to pH 5.6.

⁵Lime to pH 6.0.

Effects of nitrogen fertilizer on soil pH

Use of common nitrogen fertilizers increases soil acidity and the need for lime. Table 9 shows the effects of increasing nitrogen rates on soil pH in four southern Willamette Valley, Oregon soils. Urea or other ammoniacal nitrogen sources acidify the top 3 inches of soil approximately 0.1 pH unit for each 100 lb N/acre. For example, if nitrogen is applied at the rate of 140 lb/acre, the soil pH will decrease by approximately 0.14 pH unit. If 140 lb N/acre is used for 3 years, soil pH will decline approximately 0.4 pH unit.

Therefore, applying excessive nitrogen fertilizers has a double cost. The first cost, the fertilizer itself, is not offset by increased yields or economic returns. Second, the additional nitrogen acidifies the soil, which then requires additional lime to raise the soil pH. Applying 50 lb N/acre above a crop's need will require an additional 0.3 to 0.6 ton lime/acre in 3 years.

Urea is the most common solid or dry nitrogen source. It is less acidifying than ammonium sulfate because the nitrogen in urea undergoes a different process to become available to plants. As urea initially reacts with enzymes in the soil, the soil pH rises slightly. This slight rise in pH

partially offsets acidification produced by subsequent reactions.

Of the commonly available nitrogen sources, ammonium sulfate is the most acidifying. Ammonium sulfate can be useful in reducing soil pH on sites with mildly alkaline soils.

Foliar fertilization

While foliar sprays have proven effective for applying zinc, boron, and other micronutrients, foliar applications have not proven very effective for meeting raspberry nitrogen needs. Broadcast granular applications or liquid applications through drip irrigation systems are recommended for fertilizing red raspberries.

Phosphorus (P)

Most soils in Oregon's Willamette Valley contain adequate available phosphorus for red raspberry production. The same is true for many northwestern soils.

On acidic, volcanic ash-influenced soils in the Cascade Mountains and in northern Idaho, available phosphorus concentrations can be limiting for some crops. However, there is no definitive research showing yield or growth responses from phosphorus applications to red raspberry. Trial applications can help determine phosphorus needs for individual fields

Table 10. Phosphorus recommendations for red raspberries.

If P soil test value is ¹		If tissue P is ² (%)	Apply this amount of P ₂ O ₅ (lb/acre)
Bray extractant (ppm)	Olsen extractant (ppm)		
0–20	0–10	Below 0.16	60–80
20–40	10–20	0.16–0.18	0–60
Over 40	Over 20	Over 0.18	0

¹Use soil tests only for preplant applications. Use the Bray soil test west of the Cascade Mountains and the Olsen or bicarbonate test east of the Cascades.

²Late-July to early-August tissue tests (for established crops).

when tissue phosphorus concentrations are below normal. Use Table 10 for guidance. Tissue testing for 3 to 5 years may be necessary before differences are observed.

Surface applications of phosphorus are less effective than subsurface banding due to lack of mobility in soil. Rates in Table 10 are for subsurface bands. For the fastest and most efficient movement of phosphorus to raspberry roots, place bands adjacent to hills on each side of the row and 4 to 6 inches deep. Double or triple the phosphorus rates in Table 10 for a preplant, broadcast, incorporated application.

Rock phosphate can be used by growers practicing organic production. Not all rock phosphates react or release phosphorus at the same rate. Finely ground rock phosphate mined in North Carolina, when applied to a phosphorus-deficient soil at double the rate of super phosphates, produced wheat yields comparable to those produced by super phosphate. Rock phosphate material has approximately 30 percent P_2O_5 , with a citric acid solubility above 50 percent.

Potassium (K)

Potassium is essential for red raspberry production; however, the amount of potassium fertilizer required is not well defined. Good fruit firmness sometimes

is attributed to adequate tissue potassium levels. While the importance of potassium nutrition in plant cold hardiness often is cited, no documentation exists to support the idea that higher than adequate tissue potassium concentrations increase cold hardiness.

Use soil tests to determine preplant potassium fertilization. Tissue analysis is the best indicator of potassium needs after crop establishment. Generally, little or no correlation exists between soil and tissue potassium levels. High surface soil potassium and low tissue potassium may indicate a gravelly subsoil low in potassium, inadequate irrigation, diseases, or other production problems.

In new plantings, one-half to two-thirds of the potassium requirement can be broadcast and incorporated before planting. The remaining one-half to one-third can be banded with nitrogen and phosphorus after planting. No more than 40 to 60 lb K_2O /acre should be included in N-P-K mixtures banded after planting. Excessive amounts of banded potassium can cause burning of new roots, particularly in sandy soils.

In fields 2 years old or older, potassium can be banded or broadcast, alone or in combination with nitrogen, phosphorus, and possibly other fertilizers. Use Table 11 to determine potassium fertilizer rates.

Table 11. Potassium recommendations for red raspberries.

If soil K test value is ¹ (ppm)	If tissue K is ² (%)	Apply this amount of potash (K_2O) (lb/acre)
Below 150	Below 1.0	60–100
150–350	1.00–1.25	40–60
Over 350	Over 2.0	0

¹Preplant ammonium acetate soil test.

²Late-July to early-August tissue test (for established crop).

Sulfur (S)

Sulfur deficiencies in raspberry crops are not common in much of the Pacific Northwest. Sulfur deficiencies have been reported in some areas, however, most notably on sandy soils in Washington’s Skagit Valley.

Soil sulfur concentrations usually are adequate in raspberry fields because sulfur often is added with other nutrients in fertilizers. Fertilizer materials such as ammonium sulfate (21-0-0), potassium sulfate (0-0-50), and gypsum contain sulfur.

For plantation establishment, apply 30 lb actual sulfur/acre if the preplant soil test is below 10 ppm. No sulfur should be needed if the soil test is above 10 ppm, assuming that pH is between about 5.6 and 7.0.

Like nitrogen, sulfur is a key component of proteins. Tissue sulfur concentrations between 0.11 and 0.2 percent generally are adequate. The ratio of total nitrogen to total sulfur in tissue typically is 15:1. For example, when tissue nitrogen is 3 percent, a 15:1 nitrogen-to-sulfur ratio would mean 0.2 percent sulfur. For a 3 percent tissue nitrogen concentration, a tissue sulfur concentration of 0.1 percent would create an N:S ratio of 30:1. Sulfur is likely to be deficient if the N:S ratio is greater than 20:1. When using the ratio approach to estimate S sufficiency, be sure that tissue nitrogen and sulfur are not both low.

When sulfur applications are needed, 30 to 40 lb actual sulfur/acre is adequate. Gypsum is a common source of sulfur and has little impact on soil pH. When soil pH values are higher than desired and sulfur is needed, elemental sulfur can be used to lower soil pH while providing the needed sulfur.

Micronutrients

Boron (B)

Small amounts of boron are critical for bud break and fruit set of red raspberries. Boron deficiency results in small fruit, decreased yields, and, in severe situations, cane dieback. Table 12 provides boron fertilizer recommendations based on soil or tissue tests. Note, however, that soil tests are less effective than tissue tests at predicting boron needs for fruit crops.

Boron applications without soil or tissue tests are not recommended because boron is toxic to plants at very low concentrations. In an Oregon trial, continued application of boron reduced yields 2 years in 5 when tissue boron was adequate.

Do not apply boron to the soil in bands along the berry rows. Either broadcast boron or apply it as a foliar spray. Broadcast solid boron-containing fertilizers throughout the plantation to avoid high concentrations within the crop rows. Foliar boron applications in fall or spring prior to

Table 12. Boron recommendations for red raspberries.

If soil B test value is ¹ (ppm)	If tissue B is ² (%)	Apply this amount of B (lb/acre)
Below 0.5	Below 25	2.0–2.5
0.5–1.5	25–30	1.0–2.0
Over 1.5	Over 30	0

¹Preplant hot water extractable soil test.

²Late-July to early-August tissue test (for established crops).

bloom are effective. Boron can be added to most sprays, particularly Bordeaux mixture.

Other micronutrients

Other than boron, micronutrient applications have not been shown to increase growth or yield of red raspberries in western Oregon trials. Soils within the Pacific Northwest vary greatly, however, and raspberry production outside of western Oregon may require supplemental micronutrient applications to soils or plants.

Iron nutrition can be complicated, particularly on alkaline and/or poorly drained soils. Iron (Fe) concentrations in soil and tissue often correlate poorly with plant performance. Under certain conditions, both soil and tissue tests may show abundant iron concentrations while the plants show symptoms of iron chlorosis—yellow or dead tissues between dark green veins on the leaves.

Keeping soil pH values neutral to moderately acidic (5.6 to 7.0) and providing adequate water drainage usually prevents iron deficiency problems. On alkaline soils where iron and other micronutrient availability is limited, foliar fertilizer applications often are used for fruit production.

Soil pH, acidity, and alkalinity

Acidity or pH is the most commonly determined chemical characteristic of soil. Soil pH is a chemical property of soil that largely determines the suitability for root growth. Acidity is a measure of the hydrogen ion concentration in a soil solution (water held by the soil particles). Soil acidity or alkalinity is measured and expressed as soil pH on a scale from 0 to 14. Soil pH values below 7 indicate acidic soils, and numbers above 7 indicate basic or alkaline soils. As pH values decrease,

soil acidity (the hydrogen ion concentration) increases.

Soil pH tells us the chemical conditions roots will experience. As soil pH decreases, the solubility of iron, zinc, manganese, and aluminum increases. The concentration of manganese and aluminum can reach levels that are toxic or at least inhibit root growth. Crop sensitivity to manganese and aluminum varies, and raspberries are moderately sensitive.

As soil pH increases, the solubility of iron, zinc, and manganese decreases. The concentration of manganese and iron can reach levels that are deficient, causing yellowing of leaves.

For optimum raspberry production, maintain the soil pH between 6.2 and 6.8. Lime is added to acidic soils to raise the pH. Amendments such as elemental sulfur are added to basic soils to lower the pH.

Acidic soil and the need for lime

Soil pH determines whether lime is required. A second soil test, the lime requirement or buffer test (sometimes called SMP), provides an estimate of the amount of lime needed.

Lime is suggested when the soil pH is 5.5 or below, or when calcium (Ca) levels are below 5 meq Ca/100 g of soil. However, if total bases exceed 20 meq/100 g on fine-textured (clayey) soils, lime is probably not needed unless the pH is below 5.2.

Lime applications are most effective when the lime is mixed with the soil. For that reason, lime should be mixed into the soil at least several weeks before planting. A lime application is effective over several years.

Sandy soils to which fertilizers have not been recently applied sometimes record low pH and high SMP buffer values. In such cases, a light application of 1 to

2 tons lime/acre should suffice to neutralize soil acidity.

For acidic soils low in magnesium (less than 1 meq Mg/100 g of soil), 1 ton of dolomitic lime/acre can be used as a source of magnesium (Mg). Dolomite and ground limestone have about the same ability to neutralize soil acidity.

After planting, monitor raspberry leaf manganese (Mn) concentrations as an indicator of declining soil pH. As soil pH declines, manganese availability increases and leaf manganese concentrations rise. If leaf manganese during late July or early August is above 300 ppm, check the soil pH.

In established plantings, topdressing is the logical method for lime application. A topdress lime application should not exceed 2 tons/acre. Topdressed lime moves downward ½ to 1 inch per year until reaching a depth of 2 to 3 inches. Low soil pH below 3 inches will not be corrected by topdressing lime.

Fertilizer and Lime Materials, FG 52-E, available from the OSU Extension Service, provides additional information on lime, including an explanation of SMP buffer (see “For More Information,” page 97).

Soil acidification

While the ideal raspberry soil has a pH between about 6.2 and 6.8, commercial production is possible on sites with pH values slightly higher or lower. As soils become alkaline (pH values above 7.0), iron, manganese, and other micronutrients become less available to plants. Iron chlorosis, as well as boron, manganese, and zinc deficiencies, can occur in raspberries grown on alkaline soils. Alkaline soils are common in eastern Oregon and Washington and in southern Idaho.

On mildly alkaline soils (pH about 7.0 to 7.5), foliar micronutrient applications can be used to offset soil micronutrient deficiencies. Use of ammonium sulfate as a nitrogen source on soils with pH values above 6.5 can help maintain the pH within an acceptable range.

Attempts to lower the pH of alkaline soils with applications of sulfur or sulfur-containing compounds have been made, but with limited success. The cost of acidification can be high. In Utah research, attempts to acidify alkaline soils with an acidic, iron-rich mining by-product did not reduce iron chlorosis symptoms in raspberries or strawberries.

Table 13. Approximate nutrient and water content of fresh manures.¹

Kind of manure	Water (%)	N ² (%)	P ₂ O ₅ (%)	K ₂ O (%)
Dairy	87	0.50	0.16	0.44
Beef	82	0.65	0.43	0.53
Poultry	73	1.30	1.02	0.50
Hog	84	0.45	0.27	0.40
Sheep	73	1.00	0.36	1.00
Horse	60	0.70	0.25	0.60

¹Actual values depend on the animals' diets, environmental conditions, and how the materials are handled and stored.

²About 25 percent of the nitrogen is available the first year.

Alkaline soils often are associated with alkaline irrigation water. The combination of natural buffering by chemicals in the soil and applications of alkaline irrigation water often causes the pH to return to alkaline levels within a short time. Irrigation water pH can be adjusted by injecting various acids into the irrigation system.

Before attempting to grow raspberries commercially on alkaline soils, have the soil tested and determine what steps will be required to maintain an acceptable soil pH and adequate plant nutrition. Carefully consider whether the resulting crop yields and economic returns justify growing raspberries under these conditions.

Manure

Manure is an excellent source of plant nutrients and serves as a soil conditioner. However, its variable nutrient content, handling requirements, and nutrient release characteristics require greater grower skill compared to commercial fertilizers. Table 13 provides average nutrient contents of manures.

Using manure to supply plant nutrients requires handling more material compared to commercial fertilizers. For example, an application of 70 lb N/acre as urea (46 percent N) requires 152 lb material/acre. The same amount of nitrogen from

manure, assuming 1 percent N, requires 7,000 lb/acre. Additional manure (5,000 to 7,000 lb/acre) is required the first year, as not all of the nitrogen in manure is initially available.

The conversion of unavailable nitrogen to the available form occurs throughout the growing season. If plant demand exceeds the rate of conversion, a deficiency occurs. Conversely, if conversion to available forms is high late in the season, unwanted late-season growth might result.

Losses of nitrogen exceeding 50 percent can occur during manure storage or after application to the soil surface. Nitrogen loss is least when fresh manure is spread and worked into the soil immediately.

Manure can serve as a source of weeds and pests. Unless livestock have been fed on weed-free feed, use aged manure that has been composted at temperatures high enough to kill seeds.

Centipedelike organisms called symphylans have been reported to be a problem in western Oregon when infested manures were applied to raspberry fields. Symphylans feed on germinating seeds and young roots. High-temperature composting should reduce problems associated with manure-introduced symphylans. However, aged and composted manure contains lower nitrogen concentrations than fresh manure.

Chapter 7

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 second-year 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.

Photos of disease symptoms are found on pages 101 and 102 (Appendix B).

Use pesticides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the pesticide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

Diseases that cause symptoms on fruit

Gray mold fruit rot and cane Botrytis (*Botrytis cinerea*)

The fungus *Botrytis cinerea* infects 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 grayish-black.

Conidia also infect leaves on both fruiting laterals and primocanes. Infected leaves turn light brown and die. On dead leaves, *B. cinerea* grows 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 cinerea overwinters 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 80°F, 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,” page 33).
- 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 **(*Phytophthora fragariae* var. *rubi*)**

See page 73.

Tomato ringspot virus

See page 69.

Yellow rust **(*Phragmidium rubi-idaei*)**

See page 69.

Diseases that cause symptoms on canes and leaves

Cane blight **(*Leptosphaeria coniothyrium*)**

The fungus *Leptosphaeria coniothyrium* 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 (Plate 7). 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 (see “Primocane suppression,” page 33).
- 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*)

See page 72.

Pseudomonas blight (*Pseudomonas syringae* pv. *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 primocanes (Plate 8). 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 (*Rubus parviflorus*) is a wild host for RBDV. Remove thimbleberries from areas near raspberry fields.

Spur blight (*Didymella applanata*)

This cane and foliar disease is caused by the fungus *Didymella applanata*. 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 (see page 33).
- ‘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 lime-sulfur 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 *Xiphinema americanum* and 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 either 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

(*Phragmidium rubi-idaei*)

Yellow rust disease, sometimes called western yellow rust or cane rust, is caused by the fungus *Phragmidium rubi-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, pimple-like structures (spermatogonia) about 1 millimeter ($\frac{1}{25}$ inch) in diameter on the upper surfaces of young leaves on floricanes 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 berries 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, teliospore-bearing 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 (see page 33) helps to control yellow rust by eliminating susceptible tissues when spermatogonia 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 (*Armillaria* spp.)

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 difficult. 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 adjacent to infected ones. Avoid setting new plants where infected 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. This hastens 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 tumefaciens and *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 2004. Check the *Pacific Northwest Plant Disease Management Handbook* for details.

Biological control

- Dip the roots and crowns of raspberry planting stock into commercial suspensions of *Agrobacterium radiobacter* strain K84 or strain K1026 before planting.

Phytophthora root rot (*Phytophthora fragariae* var. *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 68°F.

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 (Plate 14). 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.

Floricanes 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 well-drained 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.
- Preplant 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 (*Xiphinema americanum* group)

The nematode *Xiphinema americanum* and related species, collectively known as the *X. americanum* group, 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 fishhook-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

- Preplant soil fumigation is helpful in managing this pest.

Root lesion nematode (*Pratylenchus* spp.)

While several species of root lesion nematodes (*Pratylenchus* spp.) have been associated with *Rubus* spp., only *P. penetrans* seems to cause significant root damage. *Pratylenchus penetrans* is 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

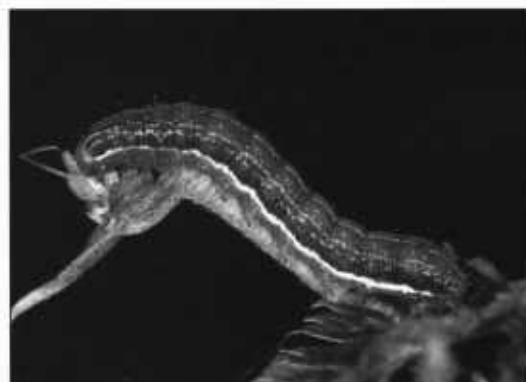
- Select sites that are free of root lesion nematodes. Sample the soil 1 year before planting to allow time for treatment if lesion nematodes are detected. Include soil and roots in samples sent for nematode analysis. Root lesion nematode populations usually are highest in late summer and fall.
- Use 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.

Chapter 8

Integrated Pest Management of Insects, Mites, and Slugs



This chapter provides information about important insect and mite pests, slugs, and snails in red raspberries in the Pacific Northwest. The life cycle of each pest is summarized, and monitoring methods are described. General information about management is provided. Photos of each pest are found in Appendix B, pages 101–104. Many more images can be found on the Internet by searching on the common or scientific name of the pest.

Because pesticide regulations and registrations change frequently, specific pesticide recommendations are not included here. For information on available pesticides, refer to the current *Pacific Northwest Insect Management Handbook* (see “For More Information,” page 97). For help with monitoring and management, contact an Extension agent or integrated pest management consultant.

Populations of pest insects and mites vary from year to year, region to region, and farm to farm. The timing of life cycles also varies from region to region.

Generally, insects appear earlier and have more generations in warmer, longer season areas than in regions where temperatures are cooler and the seasons shorter.

Pests that have been numerous for several years may seem to disappear after diligent monitoring and management. There is always a chance, however, that the pests will reappear. Regular, frequent, and thorough scouting of each field is crucial for effective pest management programs.

Appendix A (pages 99–100) contains a calendar of activities that describes when to scout for and manage pests.

Caterpillars: spanworms, leafrollers, cutworms, and loopers

Many species of caterpillars feed on raspberries, and all of them are larvae representing the immature stage of moths. Some species feed on buds and foliage, others web up against berries and feed on them, and some drop into containers of

Use pesticides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the pesticide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

fruit during machine harvest. The most serious problem caused by caterpillars is contamination of harvested fruit.

Caterpillars that feed on raspberries are commonly grouped into four categories: spanworms, loopers, leafrollers, and cutworms. All types have three pairs of front legs located behind the head, but the number of hind legs differs among species.

Spanworms. Spanworms are green with white stripes along the sides and back. They have two pairs of hind legs; the second pair is at the end of the body and looks like a single leg. Spanworms and loopers crawl in a looping manner by drawing their back legs forward and arching their body into a loop. The front legs are then pushed forward as the insect straightens out.

Loopers. Loopers also have white stripes down their sides and back, but have three pairs of hind legs.

Leafrollers. Leafrollers are straw-colored, green, or brown with a dark or light head. They have five pairs of hind legs. Leafrollers wiggle vigorously backward when disturbed and do not move in a looping fashion.

Cutworms. Cutworms are striped or patterned in various colors and have five pairs of hind legs. A cutworm often curls into a ball when touched.

Life cycles and feeding habits

Spanworms

- **Bruce spanworm:** *Operophtera bruceata*
- **Winter moth:** *Operophtera brumata*

Caterpillars belonging to these two species are almost identical (Plate 15). The larvae hatch in early spring from eggs laid in winter by wingless female moths. Larvae feed mostly on foliage, rolling and webbing leaves to create feeding shelters.

Spanworms rarely damage raspberry flower buds because they usually finish feeding before bloom. There is only one generation of larvae per year, so spanworms are not harvest contaminants.

Leafrollers

- **Orange tortrix:** *Argyrotaenia citrana*
- **Obliquebanded leafroller:** *Choristoneura rosaceana*
- **European leafroller:** *Archips rosana*
- **Dusky leafroller:** *Orthotaenia undulana*
- **Straw-colored tortrix:** *Clepsis spectrana*

Orange tortrix is the main leafroller pest in Oregon's Willamette Valley and in Washington's Skagit, Clark, and Cowlitz counties. Obliquebanded, European, and dusky leafrollers and straw-colored tortrix are more common in northwestern Washington's Whatcom County. Leafrollers also are common pests in northern Idaho.

Orange tortrix larvae are tan when small (Plate 16), changing to pale green with a tan head as they mature. There are two or three generations per year.

Larvae overwinter, often in dead leaves on canes tied to trellises. Following a mild winter, moths emerge as early as March in western Oregon and Washington, although a cold winter can delay emergence until April. Emergence occurs later in cooler, shorter season locations. Peak flights of the first generation of moths occur from late April to mid-May.

The next generation of larvae begins emerging from eggs in late May in western Oregon and Washington. Generations of moths and larvae overlap through the summer.

Larvae feed on buds and new leaves, rolling and tying older leaves around the feeding site. Larvae sometimes also feed

on ripe fruit. Orange tortrix larvae often are the main insect contaminant at harvest in Oregon.

Obliquebanded leafroller larvae are tan when small and later turn leaf green with a black or brown head (Plate 17). There are two generations per year.

Very small larvae overwinter and resume feeding in April and May, as buds and new leaves are growing. Larvae finish feeding and pupate in May. Moths emerge, mate, and lay eggs (Plate 18) in June.

The second generation of larvae feeds from June through August. Second-generation moths emerge, mate, and lay eggs from late July through August. Larvae that hatch from summer eggs feed until they have molted once or twice, then stop feeding and seek overwintering sites under buds and bark on canes.

European leafroller (Plate 19) overwinters as eggs and has only one generation per year. Larval emergence coincides with the first generation of obliquebanded leafroller. Less is known about the dusky leafroller (Plate 20), but its larval emergence also coincides with the first generation of obliquebanded leafroller. Straw-colored tortrix (Plate 21) produces two generations per year, similar in timing to obliquebanded leafroller. Straw-colored tortrix is an infrequent but increasing pest.

Cutworms

- **Spotted cutworm:** *Xestia (Amathes) c-nigrum*
- **Variegated cutworm:** *Peridroma saucia*
- **Bertha armyworm:** *Mamestra configurata*
- **Zebra caterpillar:** *Melanchra picta*
- **Brown fruitworm:** *Eupsilia tristigmata*
- **Speckled green fruitworm:** *Orthosia hibisci*

Spotted cutworm has a reddish brown head and body, and the head has two black bands (Plate 22). These caterpillars are likely to feed on buds in early spring. The larvae overwinter in the soil and feed whenever the temperature is at or above 40 to 50°F. Following pupation in the soil, moths emerge from May through July. They lay eggs, and a second generation of larvae feeds from June through August. The second generation of moths is present from August through October.

Variegated cutworms are mottled dark brown or black with a yellow lateral band (Plate 23). The life cycle is similar to that of spotted cutworm.

Bertha armyworm larvae are green, gray, brown, or black with a lateral orange or yellow stripe (Plate 24). There are two generations per year, with the pupae overwintering in the soil. Adults emerge in April, mate, and lay eggs. The larvae disperse on silken threads and then feed for 5 or 6 weeks until June or July. Pupation occurs in the soil, followed by the emergence of a second generation of adults. Second-generation larvae feed in late summer and fall.

Zebra caterpillar, named for its colorful pattern of zigzagging white stripes and lateral yellow lines on black (Plate 25), produces two generations per year. There are conflicting reports that it overwinters as a larva, pupa, or egg. Larvae can be found on the plants from June through September. Moths are present in July and September.

Brown fruitworm larvae are reddish brown with a brown head (Plate 26). They produce one generation per year. Brown fruitworm moths overwinter, and larvae are present from April through June. Speckled green fruitworm larvae are green with five lateral white stripes and many white speckles (Plate 27). Pupae

overwinter in the soil. The adults emerge in very early spring, and larvae feed during April and May.

Loopers

- **Alfalfa looper:** *Autographa californica*
- **Raspberry looper:** *Autographa ampla*

Alfalfa looper produces at least two generations per year, while raspberry looper produces one. Alfalfa looper overwinters as a pupa in the soil, and the moths are present from April through May and June through July. The larvae feed from May through June and July through August. Raspberry looper overwinters as a larva, pupates from May through July, and emerges as a moth during June and July. The larvae (Plate 28) feed from June through the summer.

Monitoring

Begin monitoring for caterpillars when plants leaf out in spring. Caterpillar outbreaks can happen quickly, so monitor every few days, if possible, during early through late spring.

Examine buds and new growth in several areas within each field for signs of leafroller, spanworm, and cutworm feeding and damage. If leafrollers and spanworms are present, they will be found in damaged buds and rolled leaves. If damage is found but caterpillars are not present, search the base of the plant at night for cutworms. These pests feed at night and return to the soil during the day.

As the canopy fills in, visual inspection becomes more difficult. During May and June, sample with a beating tray, or spread a white sheet on the ground and tap the canes and wires above it. Caterpillars and other pests will fall onto the beating tray or sheet.

Where cutworm damage is suspected, dig into the soil at the base of the plants to

search for cutworm larvae. Just after dusk, tap the canes and wires over a beating tray to detect cutworms.

Place pheromone traps for orange tortrix in the fields by April 1. Place pheromone traps for obliquebanded leafroller during mid-May. Check the traps weekly and remove trapped moths. Plot the number of moths per week on a graph. Once the number of moths per week has peaked, expect the second generation of caterpillars to appear. Continue to monitor for larvae as described above. The number of orange tortrix moths trapped provides a conservative estimate of the potential infestation by orange tortrix caterpillars. The relationship between trapped obliquebanded leafroller moths and subsequent larval populations is less predictive.

Harvesting machines are excellent monitoring tools for caterpillars and other contaminants. Ride the harvester and note what types of caterpillars come across the belt.

Management

Cultural practices can reduce orange tortrix populations. Remove overwintering sites by destroying old canes in the fall, delaying trellising until most leaves have dropped, and tying canes loosely to the trellises. Remove woody plants along fence rows to deprive orange tortrix females of egg-laying sites.

There are three main times for making management decisions about caterpillars: the dormant to prebloom period (March to mid-May); bloom to preharvest (mid-May through June); and harvest (July and August). The actual times may be several weeks later on cooler sites in and east of the Cascade Mountains.

During the dormant to prebloom period, the goal is to protect buds and new growth from caterpillar feeding. During bloom to

preharvest, the goal is to reduce the contamination of harvested fruit. During harvest, the goal is to kill contaminants.

When moths are flying and laying eggs, you can purchase tiny parasitic wasps (*Trichogramma*) and spread them throughout the fields. *Trichogramma* parasitizes eggs of leafrollers, cutworms, and loopers, preventing caterpillars from emerging. *Trichogramma* has been reported to be very effective in some cases.

If monitoring indicates that caterpillars are present throughout a field or are numerous in several patches in a field, consider insecticide treatments. Choose an insecticide registered for the target pest, and respect the preharvest interval. If pollinators are in the field, choose an insecticide that is nontoxic to bees, such as a *Bacillus thuringiensis*-based product.

Before applying chemical insecticides, consider that many beneficial insects and spiders play important roles in reducing caterpillar populations. These predators are killed by many chemical insecticides. Using chemical insecticides can lead to outbreaks of twospotted mites.

Noncaterpillar insect pests

Raspberry beetle (*Byturus unicolor*)

Raspberry beetle (formerly known as Western raspberry fruitworm) is distributed throughout raspberry-growing regions of the United States and Canada. It is a key contaminant of machine-harvested raspberries in northwestern Washington and in British Columbia. Handpicked berries are also affected by raspberry beetle infestations, which reduce fruit shelf life. Tolerances for contamination by this beetle vary, depending on the harvest grade and product.

Adult raspberry beetles are small ($\frac{1}{8}$ inch), oval, and brown (Plate 29). Raspberry beetle larvae are grublike and segmented, with tan plates. They are about $\frac{1}{3}$ inch long when mature.

Life cycle and feeding habits

Adult beetles emerge from the soil and begin flying in April, with flights continuing into August. Adult damage to raspberry foliage appears as scalloped chew marks along leaf edges and between leaf veins (Plate 30). Adults also feed on developing flower buds and flower parts. Small, oval eggs are deposited on developing buds or inside flowers and developing fruit.

The larvae feed inside developing raspberry fruits on the receptacles (Plate 31). They occasionally feed on developing drupelets, causing deformed and discolored fruit. Larvae drop to the soil and pupate in fall. The larval stage is the common contaminant of machine-harvested raspberries.

Raspberry beetles also infest other *Rubus* species with flowering times similar to those of summer-bearing red raspberries.

Monitoring

Beginning in April, inspect foliage and developing buds for adult beetles and feeding damage. Beetles are highly attracted to sticky traps made from non-ultraviolet white cardboard. Such traps are very effective for monitoring beetle flight activity and abundance. Place traps along field perimeters adjacent to neighboring raspberry fields or other *Rubus* hosts.

Management

Preventive insecticides can be applied prior to flowering or when 5 percent of the flowers are open, just prior to setting out

pollinators. Integrated pest management strategies are being developed to offer alternative management options.

Large raspberry aphid **(*Amphorophora agathonica*)**

The large raspberry aphid occasionally contaminates machine-harvested raspberries. Large aphid populations support large populations of predators, including ladybird beetles and green lacewing larvae, which also contaminate fruit at harvest.

Aphid feeding causes wilting and deformation of new canes and leaves, and large populations can defoliate raspberry plants. Excessive honeydew (aphid excretion) on foliage and fruit can promote the growth of molds. Raspberry aphid is the vector of raspberry mosaic virus, which can cause significant yield loss, but this virus is not common in the Pacific Northwest.

Large raspberry aphids are $\frac{1}{8}$ inch long with a pear-shape, yellow-green body (Plate 32). Two protuberances (cornicles), which emerge from the end of the body, distinguish aphids from other insects. Adult aphids can be winged or wingless.

Life cycle and feeding habits

Females give live birth to female nymphs through a process called parthenogenesis. Males are produced only in the fall. Mated females lay eggs in crevices on raspberry canes. The nymphs emerge in spring and begin to feed on new growth.

Monitoring

Begin monitoring for aphids in late spring and early summer. Inspect primocane tips and the undersides of leaves for aphid colonies. A beating tray is useful for monitoring aphids and aphid predators.

Management

Aphids are occasional pests and rarely need management if no virus is present in the area. Plant certified stock that is free of raspberry mosaic virus, and use aphid- and virus-resistant cultivars. If the virus is present, consider managing the aphids when more than two aphids are observed per cane tip.

Predators and parasitoids can help manage aphid populations if broad-spectrum insecticide applications are reduced prior to harvest. Adjustments to the belt and fan of harvesting equipment can reduce the degree of aphid and aphid predator contamination.

High aphid populations can be controlled with a preharvest insecticide application. Additional treatments using insecticides, insecticidal soaps, and entomopathic fungi help suppress aphid problems at harvest. Postharvest management of high aphid populations may not be necessary if the growing season is nearing its end.

Root weevils

- **Black vine weevil:** *Otiorhynchus sulcatus*
- **Strawberry root weevil:** *Otiorhynchus ovatus*
- **Rough strawberry root weevil:** *Otiorhynchus rugosostriatus*
- **Clay-colored weevil:** *Otiorhynchus singularis*

Black vine weevil (Plate 33), strawberry root weevil (Plate 34), rough strawberry root weevil (Plate 35), and clay-colored weevil (Plate 36) are common and important contaminants of machine-harvested red raspberries in the Pacific Northwest. Root weevils belong to a subfamily of

“broad-nosed” weevils that have chewing mouthparts at the end of a long rostrum (snout). These weevils have a hard, ¼- to ½-inch-long body that generally is shiny black, reddish black, or mottled sandy to dark brown. Only females have been found, and all are wingless. The C-shape larvae (Plate 37) are legless and have a pinkish to yellowish body, brownish head capsule, and chewing mouthparts.

Life cycle and feeding habits

Root weevil larvae are adapted for grazing small roots and girdling roots and stems. Larvae can live for 9 months in the soil, during which their feeding causes serious injury to plant roots.

The adults generally live and lay eggs in soil crevices during the day or drop the eggs to the ground at night while feeding. They commonly are active between 10 p.m. and 2 a.m. The characteristic notches left by adult feeding on leaves (Plate 38) generally do not cause economically important damage, although feeding on buds and lateral shoots by the clay-colored weevil can reduce yields.

One generation is produced each year, and the life cycle is similar for all species of *Otiorhynchus*. Most root weevils overwinter as late-stage larvae or prepupae in cells found about 6 inches deep in the soil. Some weevils also overwinter as late-maturing adults and emerge as viable females that begin laying eggs in late April or early May during their second year. If not controlled, these early-emerging females can lay 600 to 700 eggs during the growing season. Females that emerge in mid-May and early June from overwintered pupae lay about half as many eggs as the overwintering females.

The first larval emergence occurs in early July and peaks in late September. Upon hatching, the first-stage larvae

burrow into the soil to feed on raspberry rootlets. Root weevils develop and grow through six or seven molts.

Monitoring

During bud break and development of floricanes laterals, use a canvas- or cloth-covered beating tray to detect early-season clay-colored weevil and rough strawberry root weevil. Sample in early morning or late evening. A typical survey might include taking 10 samples from each of 3 to 5 sites within a field.

Clay-colored and rough strawberry root weevils are adapted to cool temperatures and are rarely detected during the preharvest and harvest periods when air temperatures exceed their activity threshold. Notched and flagged fruiting laterals or chewed fruit buds indicate the presence of clay-colored weevil and woods weevil.

Black vine and strawberry root weevils are active during preharvest and harvest. Notching of leaf margins from mid-May to late June (the preoviposition period) indicates weevil infestations. Beetles feed on foliage at night, so search with a flashlight and beating tray to identify species and their relative population levels. Or, spread a 3-foot by 10-foot white drop cloth on either side of the row and shake the top training wire vigorously about 10 times to dislodge feeding weevils.

Management

Root weevil control strategies must be directed at both generations of adults during their prolonged pre-egg-laying period of 4 to 9 weeks. If not controlled with a preharvest treatment, both generations of weevils can become serious harvest contaminants. Eggs laid during harvest produce overwintering larvae and adults for the following season.

For machine-harvested red raspberries, weevil control requires insecticides to maintain the zero tolerance set by the processing industry. A prebloom insecticide application provides effective control of clay-colored and other overwintering adult root weevils. Researchers in the Pacific Northwest recommend weevilicide application when 1 clay-colored weevil appears for each 10 beating tray samples. The insecticide normally is applied to the basal portion (lower 4 feet) of the canes. If necessary, an over-the-row insecticide application can be used during prebloom to control both adult root weevils and raspberry beetle adults.

Growers typically apply a preharvest cleanup spray to control insects through the harvest period. This practice has provided excellent control of preovipositing, summer-generation weevils.

Research is underway on several new soil-applied insecticides that target root weevil larvae. It is hoped that these products will provide red raspberry growers with options for dealing with overlapping generations, egg-laying periods, feeding behaviors, and labeling issues (e.g., preharvest intervals, reentry intervals, and insecticide rate and application regulations).

Raspberry crown borer (*Pennisetia marginata*)

Raspberry crown borer is an important pest of red raspberries in North America. Raspberry crown borers are clearwing moths that closely resemble yellow jacket wasps (Plate 39). The larvae are cream colored with a dark head capsule. The larvae bore into raspberry canes, causing poor cane vigor, spindly canes, and cane death. Raspberry crown borer can limit a region's potential for producing commercial raspberries. Borer populations increase rapidly if unmanaged.

Life cycle and feeding habits

The life cycle of the raspberry crown borer takes 2 years to complete. Moths fly during daylight from mid-July through September. After mating, the females deposit small, dark, oval eggs along the underside margins of raspberry leaves. The eggs hatch in the fall, and the larvae migrate to the bases of the canes. These larvae overwinter in silken structures on the sides of the canes just above the soil line. Camouflaging debris is attached to the refuges.

In spring, the larvae feed by boring into the soft pith of the canes, girdling new canes. Larval development continues inside the canes and root crowns for the rest of the year. The following spring, mature larvae a little more than 1½ inches long migrate up the centers of the canes and pupate about 4 inches above the soil (Plate 40). Adults emerge from the canes in July.

Monitoring

During spring and fall, regularly scout raspberry fields for areas that seem to be weakened. Look for spindly canes and wilting primocanes. Infested canes can be easily pulled from the crown. Look for swellings at the cane's base and crown. Examine suspect canes by cutting into the root crown and looking for tunneling and frass inside the stem and crown. During the fall, watch for the blisterlike, silken refuges in which the larvae overwinter.

Pheromone lures are available for monitoring adult male flights, but the lures have not yet proven reliable.

Management

Insecticides can be applied as soil drenches in infested fields between November and March to control young, overwintering larvae. Because raspberry

crown borer has a 2-year life cycle, apply the drenches for 2 consecutive years. No treatment should be required the third year.

Spider mites

- **Twospotted spider mite:** *Tetranychus urticae*
- **McDaniel spider mite:** *Tetranychus mcdanieli*
- **Yellow spider mite:** *Eotetranychus carpini borealis*
- **European red mite:** *Panonychus ulmi*

Four species of spider mites are found in red raspberries in the Pacific Northwest. The twospotted spider mite (Plate 41) was the only economically important spider mite species reported on red raspberries for decades. Yellow spider mite (Plate 42) was first reported in 1992. The European red mite (Plate 43) was identified in 1995 in Washington's Whatcom and Skagit counties. A common tree fruit species, it occurs mostly in northwestern Washington. It is becoming more widespread, however, for reasons that are not clear. The McDaniel spider mite (Plate 44) was identified in 1997 in Washington's Clark County.

Red raspberry responses to spider mite feeding include chlorotic (yellow or white) stippling on leaf surfaces, reduced flower bud formation, reduced yield, premature leaf fall, and even plant death. High densities of mites can result in defoliation and leave the plants covered in dense webbing.

The larvae look like small adults, but have only three pairs of legs. Nymphs also look like small adults but have four pairs of legs.

Life cycle and feeding habits

Adult and juvenile spider mites feed by inserting their piercing-sucking stylet mouthparts into plant tissues and removing

plant juices. They can inject salivary toxins, enzymes, and hormonelike substances into the feeding puncture.

Female spider mites usually lay eggs on the undersides of leaves. The larval stage is followed by two nymphal stages. Each juvenile feeding stage is followed by a resting stage known as nymphochrysalis, deutochrysalis, and teliochrysalis, respectively. The time required for the pest to develop varies with temperature, humidity, host plant, and leaf age. Hot, dry conditions favor spider mite outbreaks.

Spider mite populations can increase during bloom and preharvest. Populations vary from field to field, depending on heat unit accumulations and cultural practices. Field populations of twospotted spider mite can increase rapidly after harvest through early September.

Yellow spider mites and twospotted spider mites often are found in mixed populations on the same leaves during the harvest period. The yellow spider mite emerges earlier than the twospotted spider mite. Yellow spider mites migrate from overwintering sites to foliage along the top trellis wires as early as April to May. They also remain on primocane foliage later in the season than twospotted spider mites.

The population dynamics, feeding, and webbing behavior of the McDaniel spider mite are very similar to those of the twospotted spider mite. McDaniel spider mite is adapted to eastern Washington, but responds quickly to warm summer weather in western Oregon and Washington. If uncontrolled, this species can severely bronze and defoliate foliage during July, and fruit exposed to sunlight becomes soft and misshapen.

All developmental stages of spider mites may be present on floricanes and primocane foliage during the harvest period. By mid-August, twospotted, yellow, and

McDaniel spider mites undergo natural seasonal declines. Populations also are reduced at this time by predatory phyto-seiid mites and predatory bugs.

Monitoring

In May, begin inspecting florican foliage in the middle and upper canopy. Look for emerging overwintering adults or newly hatched European red mite larvae. Signs include patches of stippling along the upper midrib area of florican leaves. Remove leaflets and examine them with a 10X hand lens. Collect random leaf samples at least every 2 weeks during May and June and more frequently during harvest. Keep seasonal records of spider mite adults, eggs, and mite predators to identify trends and determine whether treatments are necessary.

Management

If spider mite population levels rise to the threshold of 10 to 25 per leaflet in June, one option is to apply a miticide with a short preharvest interval. During this period of low predatory mite activity, spider mite populations can rapidly increase to 300 or more immature mites and adults per leaflet by September. After harvest, good canopy penetration and coverage with a miticide can be difficult because of lush foliage and primocane lodging. Well-planned and implemented integrated control strategies for spider mites can help reduce miticide applications. Newer miticides are more selective for spider mite pests and safer to predatory mites and insects than older pesticides.

Slugs and snails

(Deroceras, Arion, and Helix spp.)

Slugs and snails can contaminate machine-picked raspberries, and their feeding on foliage can reduce bud and primocane growth early in the growing season. Characteristic, silvery slime trails are diagnostic of these pests.

Life cycle and feeding habits

Slugs and snails reproduce whenever conditions are cool and wet. These pests can live for several years and lay hundreds of eggs each year. They feed on foliage on the lower parts of floricanes and primocanes as well as on developing primocanes. Slugs and snails often can be seen at night, but they seek shelter during daylight.

Monitoring

Scout for slug and snail damage during cool, wet periods. Regularly check berry flats left in the field during harvest.

Management

Slugs and snails rarely require pesticide applications. Because they can contaminate berry flats left in the field, store flats off the ground and clean flats regularly. Keep grasses and weeds around berry fields mown short. Use slug baits and pesticides only if slug populations need to be reduced.

Chapter 9

Organic Production



Throughout this guide, we have emphasized environmentally sound practices, beginning with site and cultivar selection. Chapters on plantation preparation and establishment apply equally to conventional and organic growers. Conventional and organic fertilizer options are discussed in Chapter 6, and Chapters 7 and 8 include recommendations for cultural and biological controls in managing diseases and pests.

Topics that are unique for organic growers or that merit additional emphasis are discussed in more detail in this chapter. Bear in mind that this production guide does not replace national certification standards, nor does it describe all of the practices and materials available to organic farmers. For complete information on organic certification, contact your state department of agriculture or an organic certification agency in your region.

The U.S. organic food industry has grown at a rate of 20 to 30 percent each year for more than a decade. Organically

produced raspberries may offer growers a profitable option for processing, IQF, and fresh markets. Until 2002, organic laws and regulations differed among certifying agencies across the U.S., and organic farming practices and produce quality varied greatly among growers. In addition, some farmers marketed produce as “organic” when it was not certified or did not follow organic production guidelines. This situation led to confusion in the marketplace.

Besides the inconsistency in rules and regulations, organic production practices were not well understood or documented by traditional scientists. Many researchers did not include organic or nonchemical control options in their studies, and generation of science-based information for organic production has been slow.

Today, efforts by organic producers, researchers, and state and federal legislators have produced uniform national guidelines for growers and marketers. Allowable farming practices, pesticides,

and fertilizers are more clearly defined by law. In order to market produce as “organic,” farmers must comply with national certification standards and must be certified by a USDA-accredited agency.

Organic production encourages limited use of off-farm products and application of nonsynthetic and less toxic fertilizers and pesticides than those typically used on traditional farms. Organic growers typically emphasize long-term sustainable production practices.

Profitability can be a problem in organic systems because reduced pesticide and synthetic fertilizer inputs often are offset by increased labor and machine costs. Also, some popular organic fertilizers, pesticides, and soil amendments can be relatively expensive to purchase or transport. Opportunities for grower profits lie in the fact that some consumers perceive organically grown produce to be safer for themselves and the environment, and they are willing to pay premium prices for such produce.

Site history

Previous land use is an important factor to consider when selecting a site for organic raspberry production. Organic certification requires that no prohibited materials be applied within 3 years of certification. Some farm and orchard pesticides used in the 1900s, such as arsenic and mercury, can remain in the soil for long periods of time and make organic certification difficult or impossible. Before purchasing land or investing in the transition to organic production, conduct soil tests to identify potential problems with residual pesticides and other banned substances. Likewise, determine whether pesticide drift or runoff from adjacent farms or pesticide-contaminated irrigation water might interfere with organic certification.

Diseases from previous crops can interfere with organic production. Sites that have been planted to peaches, apples, grapes, brambles, blueberries, and other woody fruit crops may harbor crown gall pathogens in the soil that could be transmitted to new plantings of raspberries. Planting raspberries following crops of tomatoes, potatoes, peppers, eggplants, and strawberries increases the risk of *Verticillium* wilt. To reduce the risk of these problems, document as completely as possible the history of your site, particularly with regard to crops grown and pesticides applied.

Evaluate the prospective planting site critically with regard to air circulation and water drainage. Selecting a site that allows cold air to drain quickly away from the planting reduces the risk of chronic frost and freezing injury, thereby reducing the risk of crown gall. Effective air drainage and circulation reduce humidity around the canes, thereby reducing the risk of spur blight, anthracnose, powdery mildew, fruit rots, and other diseases. Raspberries grown on sites with wet or otherwise poorly drained soils are particularly susceptible to root rot.

Site preparation

As a general rule, spend at least 1 year preparing a site before planting raspberries. Whenever possible, remove wild blackberries, salmonberries, and thimbleberries near raspberry fields to reduce the risk of transmitting pests and diseases. A minimum of 300 to 400 feet of separation from wild or cultivated berries is advisable.

Weeds, particularly invasive perennial weeds such as quackgrass, can seriously interfere with organic raspberry production. Eradicate serious perennial weeds before planting.

In conventional raspberry production, most weeds can be eradicated quite easily before planting by using contact, translocatable herbicides such as glyphosate. The advantage of these types of herbicides is that they have no residual soil activity. When planting on a new site or transitioning from conventional to organic production, growers who have serious weed infestations may choose to use nonorganic herbicides to eradicate weeds before planting, understanding that the farm cannot be certified until 3 years after the final herbicide application.

Where site cleanup with herbicides is not desirable, combine soil cultivation, fallowing, green manure crops, cover crops, soil solarization, and hand weeding to manage weeds. These options are discussed in Chapter 5.

Organic production systems emphasize building high concentrations of soil organic matter to enhance soil microbial activity, soil tilth (structure), and plant nutrition. Organic matter refers to the humic acids and other compounds that bind soil particles together in aggregates or clumps. Aggregate formation creates pores in the soil that provide for root growth, water retention and drainage, and gas exchange between the soil and atmosphere. These aggregates and pores are essential for root and microbial growth.

Raspberries tolerate a wide range of soils with concentrations of organic matter ranging from very high to very low. Typical agricultural soils contain around 3 to 5 percent organic matter. Sandy soils often contain less. Chunks of bark, straw, and other visible plant and animal debris do not contribute directly to aggregate formation and generally are not measured in soil organic matter tests.

Rather than focusing solely on organic matter, strive to maintain soil drainage,

tilth, fertility, and moisture as discussed earlier in this guide. Adding large amounts of bark, compost, sawdust, or other plant residues to the soil seldom compensates for inherently poor soil conditions. Adding organic materials to heavy clay, for example, does not improve soil drainage and can actually aggravate drainage problems. On a poorly drained site, grading the site, installing drainage tiles, and growing the crop on raised beds are more effective.

On droughty sites with sandy soils, additions of organic matter can increase the water-holding capacity of the soil. Depending on the soil, however, the volume of organic matter required can be prohibitively expensive to purchase, transport, and apply.

When soil organic matter concentrations are too low, growing green manure crops before planting raspberries can be beneficial. As the green manure crop residue degrades, it contributes organic matter to the soil and can improve soil tilth. Generally, crops that produce large amounts of residue are the most popular as green manures. Such crops include cereal grains, sweet clover, Sudangrass, sorghum, and buckwheat. Mixtures of crops, such as cereal grains and clover, vetch, or peas, often are used.

Some canola or mustard varieties produce compounds that resemble commercial soil fumigants. These fumigant-like compounds are released after the crop is tilled into the soil. While research into the use of such crops is in the early stages, it may be possible to use certain green manure crops to add organic matter to the soil while reducing pest and disease organisms.

Regardless of the crop chosen, do not allow green manure crops to produce seed and become weeds.

Planting stock

Use disease-free, certified planting stock that is grown in accordance with regulations governing the production of nursery stock. Unfortunately, finding certified organic raspberry nursery stock can be difficult. If the grower can document that organic stock is not available, conventional nursery stock may be used and the first-year crop may be certified organic. Because interpretations of regulations change, check with your certifying agent to confirm what types of planting stock can be used by organic growers.

Pest and disease management

Select varieties that are most resistant to diseases. Because organic growers have fewer pesticide options than do conventional growers, it is critical that pest and disease problems be identified early, while they can be managed effectively. Monitoring pests and diseases involves inspecting fields at least weekly from early spring through late fall. Carry a magnifying hand lens or jeweler's loupe to identify

organisms and a notebook to record observations. Pheromone traps are commercially available for monitoring some pest populations. Scouting techniques for specific pests are discussed in Chapter 8.

Using a mix of cultural practices and organically allowable pesticides generally is more effective than relying on a single strategy. Cultural practices for pest management are discussed in Chapters 7 and 8.

Obtaining organic certification

For information on organic certification, contact your state Department of Agriculture or local Extension office. An application for certification requires site information, including acreage, cropping history, intended crops, a farm map, and a farm plan outlining soil and pest management strategies. A farm inspection, interview, and submission of chemical and fertilizer application records and sales records are also required. Annual renewal and field inspections are required to maintain certification, and sampling for pesticide residues may be required.

Chapter 10

Harvesting and Postharvest Considerations



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 machine-harvesting 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 (see Chapter 3).

Damage to fruit during harvesting was more common and severe using early-generation 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 hand-harvested 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 shown 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 percent of 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 2 (page 3), 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 creates 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 and 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 the morning and are easiest to pick at that time. 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 who picked 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 baskets have largely been replaced by clear plastic clamshell 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 high-quality raspberries, 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 flat provides better results for growers. Either way, 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 handling

areas 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 fruit handling areas.

The most common source of fruit contamination is unsanitary worker conditions that lead to contamination with human wastes. Provide workers with adequate rest 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, for example, a basket or clamshell typically is pulled 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 34°F 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 the containers to a minimum. Unlike apples and 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 34°F, the flats are

stacked onto pallets. The flats on the pallets are then wrapped in special, semipermeable, plastic film that allows some gas exchange 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 process, 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. Handle the berries as little as possible and get them to consumers quickly.

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Appendix A

Calendar of Activities

This calendar lists some of the more important activities for raspberry growers in western Oregon and Washington. The actual timing varies markedly, according to a farm's location. For growers in eastern portions of the Pacific Northwest, activities may be delayed by 1 to 2 months in late winter and spring and compressed during the late summer and fall.

January

Service and repair equipment. Examine sprayer nozzles for wear. Prune out weak canes and old fruiting wood, if not already done. Top and tie canes. Apply manure, if practical. Confirm new plant orders and arrange for beehives. Apply dormant-season sprays for pest, disease, and weed control.

February

Continue January activities. Spray for crown borers if needed and not already done. Prepare and plant new fields, weather permitting. Take soil samples for nematodes from fields to be planted next year.

March

Apply fertilizers and herbicides. Spray for crown borers, if needed. Plant new fields, weather permitting. Complete all pruning and training. Install pheromone traps for orange tortrix.

April

Apply delayed dormant sprays when buds show green tips. Begin primocane suppression, if used. Begin scouting for crown gall, spanworms, and raspberry crown borers. Install sticky traps for raspberry beetles. Fertilize newly planted fields.

May

Continue primocane suppression or mechanically remove excess canes between hills. Begin control programs for fruit rot and spur blight. Continue scouting and management programs for caterpillar pests, aphids, root weevils, crown borers, spider mites, and raspberry beetles. Install pheromone traps for obliquebanded leafrollers. Place beehives in fields. Make second nitrogen fertilizer application.

June

Arrange for picking crews, machines, flats, and containers. Place new shoots inside holding wires. Irrigate to field capacity before harvest. Continue pest and disease scouting and management programs, including those for fruit and root rot, adult root weevils, aphids, caterpillar pests, spider mites, raspberry beetles, and insect contaminant pests. Harvest begins in some locations.

continues on next page

Appendix A

Calendar of Activities (continued)

July

Begin or continue harvest. Continue fruit and root rot management and other pest and disease scouting programs, including those for root weevils, spider mites, and raspberry beetles. Irrigate only as needed. Collect tissue samples and submit them to a laboratory. Make third nitrogen fertilizer application to primocane-fruiting raspberries.

August

Continue harvest and irrigation, as needed. Cultivate and plant new cover crops. Fumigate soil to control nematodes for next spring's planting, if needed. Continue mite management program and scouting for spider mites and raspberry beetles.

September

Continue harvest of primocane-fruiting raspberries. Continue alley management programs. Continued irrigation may be needed in drier locations. Scout for raspberry crown borers. Order plants for spring planting. Begin pruning spent floricanes and pruning and training primocanes.

October

Begin removing weak shoots and old fruiting wood. In western Oregon and Washington, continue pest management programs, including those for crown borers. Collect soil samples and have them analyzed. Order fertilizers, pesticides, and other supplies and equipment for next season. Clean and winterize all equipment. Drain sprayers and irrigation systems.

November

Continue pruning. Service trellis systems. Apply lime, if needed. Western Oregon and Washington growers may need to continue herbicide programs. Apply soil drench pesticides for raspberry crown borers, if needed. (These sprays can be made through March.)

December

Apply manure. Continue pruning and trellis maintenance. Evaluate this year's operation and make plans for next season.

Appendix B

Color Plates



Plate 1. Hedgerow-grown red raspberries.



Plate 2. Hill-grown red raspberries.



Plate 3. Arc cane training.



Plate 4. V trellis.



Plate 5. Normal leaves (left) and leaves with nitrogen deficiency symptoms (right).



Plate 6. Botrytis.



Plate 7. Cane blight.



Plate 8. *Pseudomonas* blight.



Plate 9. Raspberry bushy dwarf virus.



Plate 10. Spur blight.



Plate 11. Tomato ringspot virus.

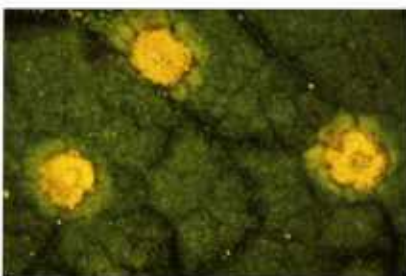


Plate 12. Yellow rust.



Plate 13. Crown gall.



Plate 14. *Phytophthora* root rot.



Plate 15. Bruce spanworm.



Plate 16. Orange tortrix larva.



Plate 17. Obliquebanded leafroller.



Plate 18. Obliquebanded leafroller egg mass.



Plate 19. European leafroller.



Plate 20. Dusky leafroller.



Plate 21. Straw-colored tortrix larva.



Plate 22. Spotted cutworm.



Plate 23. Variegated cutworm.



Plate 24. Bertha armyworm.



Plate 25. Zebra caterpillar.



Plate 26. Brown fruitworm.



Plate 27. Speckled green fruitworm.



Plate 28. Raspberry looper.



Plate 29. Raspberry beetle.



Plate 30. Raspberry beetle adult damage.



Plate 31. Raspberry beetle on fruit receptacle.



Plate 32. Large raspberry aphid.



Plate 33. Black vine weevil.



Plate 34. Strawberry root weevil.



Plate 35. Rough strawberry root weevils.



Plate 36. Clay-colored weevil.



Plate 37. Root weevil larva.



Plate 38. Adult weevil damage.



Plate 39. Raspberry crown borer adult.



Plate 40. Raspberry crown borer larva.



Plate 41. Two-spotted spider mite.

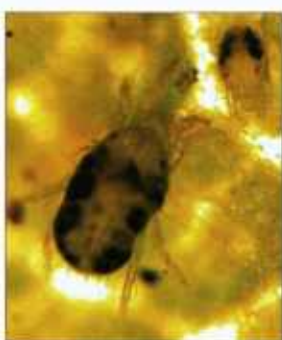


Plate 42. Yellow spider mite.



Plate 43. European red mite.



Plate 44. McDaniel spider mite.

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