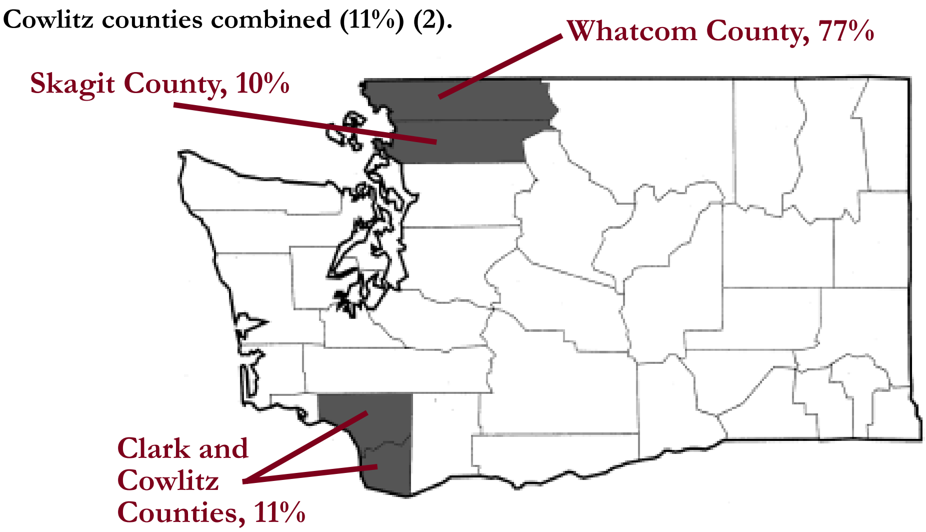
Crop Profile for Red Raspberries in Washington

Production Facts

- Washington produces 59% of the raspberries grown in the United States and over 10% of the raspberries grown worldwide (1).
- Washington is ranked first in the nation for raspberry production (2).
- From 1995 to 1997, Washington produced on average 53.2 million pounds of red raspberries per year valued at $31.2 million per year (2).
- On average, from 1995 to 1997, raspberries were grown on 6900 acres of farmland in Washington (2).
- Over this same period, average yield ranged from 6500 to 8900 pounds per acre and average price ranged from 47 to 75 cents per pound (2).
- The total average cost to produce an acre of raspberries is $3500 (1).
- Fresh market sales account for less than 2% of total production (1).

Production Regions

The entire area of Washington State west of the Cascade mountains is considered raspberry production area. However, Whatcom County produces 77% of the state total, followed by Skagit County (10%) and Clark and Cowlitz counties combined (11%) (2).



Cultural Practices

Red raspberries are a biennial, summer bearing crop. The root system is perennial and plants are capable of living for several years. Their growth habit is to produce vegetative primocanes the first year, that then become flowering and fruiting floricanes the second year, which then die. Each established field will contain both primocanes and floricanes at the time. Under ideal soil conditions and good cultural maintenance, a planting may remain productive for 10 years or more in this region. The maritime climate of western Washington, combined with well-drained, deep sandy loam soils scattered throughout the above regions makes these areas ideal for long-term commercial production (3).

Above: A row of raspberries in early June bloom period. Below: Primocane bundles tied to trellis.

Although over 10 different cultivars are grown commercially, the Meeker variety now dominates (80% of planted acres) due to several characteristics which make it suitable for both the fresh and processed markets. These include superior yield, good color and fruit firmness, compatibility with machine harvesting, vigorous growth, and relatively low susceptibility to *Phytophthora* root rot compared to other varieties. The Willamette variety accounts for 19% of total acreage, with the balancing acreage, 1% spread over several varieties picked mostly for fresh market sales (1).

A raspberry field is established by planting certified, nursery grown rootstock. Plants are set 2 to 3 ft. apart in rows about 10 ft. apart. The first year planting produces vegetative canes only (primocanes). In the fall, these primocanes are trained to a single trellis wire about 5 ft. from the ground. In mid-summer of the following season, these overwintering canes (now called floricanes) will flower and produce fruit. It is necessary to bring in honeybees for the 6 week bloom period (mid-May through late June) for adequate pollination to occur. A new flush of primocanes begins to emerge from the root crown area every spring beginning in late March. In order to maximize yield, control cane growth, and reduce fungal disease, growers practice chemical cane burning to suppress this first flush of primocanes. A second flush of primocanes emerges in mid-April, growing 8 to 12 feet tall by summer's end. Floricanes are cut out each fall after harvest, and the remaining primocanes are tied in bundles and secured to the top trellis wire. This combination of primocanes and floricanes are maintained in a hedge type row, which allows for the machine har-

vesting operation. Only fruit grown for the fresh market (<2%) is harvested by hand. The harvest period is intense and confined to a six week period from late June through early to mid-August. During this period, fields are picked on average, once every 2 to 3 days. In some cases, where fruit is destined for the high quality IQF (Individually Quick Frozen) market, fields are picked daily to maximize quality and minimize the potential for *Botrytis* fruit rot development.

Fruit on harvest machine belt.

Growers have several marketing options for their fruit. The highest value markets are the fresh and IQF markets. Intermediate in value is the processing market, and at the low end is the juice market. Prices paid to growers typically range from 30 to 40 cents per pound for juice grade up to well over a dollar per pound for the IQF and fresh markets. Superior fruit quality, in terms of fruit shape, size, and freedom from disease or insect contaminants, is a necessity, particularly in the mid and higher end markets. Growers and processors who deliver an inferior crop are likely to have the crop rejected at the point of delivery and/or may have difficulty contracting their fruit for the following season. Raspberry products which are contaminated with insects can usually be traced back through the broker, processor and to the farm. This places extreme pressure on raspberry growers to deliver a disease and insect-free, quality product, or else their livelihood is at stake. In order to meet these quality requirements, a pre-harvest "clean-up" insecticide spray must be applied to control insect contaminants. Without this application, fruit on the harvesting machine belts would literally be crawling with various worms, weevils, spiders and aphids in numbers far greater than could be hand-picked from the passing fruit. Current machine technology and structure of the fruit (hollow), require a rigorous removal of any potential insect contaminant before harvest.

Top side view from the harvest machine, looking down on picking rods, which shake the fruit from the row.

Raspberries require irrigation during the bloom, harvest, and post-harvest periods in most years depending on rainfall amounts and timing. Most fields are irrigated with either drip tape, which is buried in the soil along one edge of each row, or overhead sprinkler irrigation. The recent switch to drip irrigation is an added practice to minimize the risk of foliar, fruit, and cane diseases because these aerial plant parts are not wet as often as with overhead sprinkler irrigation. Drip irrigation also reduces the dispersal of pathogens with water-splashed spores. Weed control between the rows is accomplished largely by routine cultivation during the growing season.

Back view of mechanical harvester.

Weed control within the rows is accomplished using pre-emergent herbicides usually applied in the spring and contact herbicides as needed. Floricanes, cut from the trellis after harvest, are chopped and disced back into the soil. This practice adds organic matter and helps reduce cane disease inoculum, by subjecting the overwintering stages of cane diseases to microbial breakdown in the soil. Planting into elevated ridges is becoming quite widely practiced as a cultural method to reduce infection from *Phytophthora* and other root rotting organisms. Insect control prior to harvest is critical in order to avoid contamination of fruit by a myriad of pest and non-pest arthropods which inhabit the raspberry canopy. Fungicides are applied during the bloom period to control cane and foliar diseases and help prevent *Botrytis* fruit infection and subsequent fruit rot during harvest.

There has been a significant effort to develop IPM strategies for raspberries. A manual titled: *"Integrated Pest Management for Raspberries – A Guide for Sampling and Decision-Making for Key Raspberry Pests in Northwest Washington"* was recently completed (June 1998) by Washington State University (WSU) Cooperative Extension, Whatcom County under an EPA 319 Grant (Nooksack Watershed IPM Project). This manual was the culmination of 3 years of work with cooperation from raspberry growers, fieldmen, local community leaders, and research and extension specialists. The manual is designed to assist growers with pest identification, scouting methods, record keeping, and more knowledge-based decision-making. It is being distributed during the fall and winter of 1998 to growers, private consultants, and research and extension personnel throughout the raspberry production area. This IPM project also spawned a new cooperative effort between raspberry growers and the WSU Vancouver Research and Extension Center in the form of an on-farm research station situated in the heart of the raspberry region (Lynden, WA). This "Satellite Station" is managed by WSU research personnel and has been invaluable in facilitating on-farm research directed towards investigations of basic pest biology, pesticide performance trials, and efficacy of biorational alternatives to traditional agrichemicals.

IPM development is driven and partially limited by the requirement that fields be sprayed prior to harvest with a broad spectrum insecticide to control fruit-contaminating insects. The current material of choice (bifenthrin) provides superior insect pest control, and although it kills most beneficial insects as well as target pests, it does not seem to aggravate spider mites in a widespread or consistent fashion. One of the key, naturally occurring spider mite predators, *Amblyseius fallacis* is tolerant of this pesticide. Unfortunately, it does kill the spider mite destroyer, *Stethorus punctum picipes*, which is a very effective spider mite predator (26). A single pre-harvest application of bifenthrin usually provides adequate insect control during the entire harvest period (late June through early August).

Insect Pests

Insect pests are grouped into two major categories:

❖ Those which are mostly a concern due to their potential to contaminate fruit during the harvest period. These are discussed in this profile under the heading **Harvest Contaminants** and

❖ Those which directly damage raspberry plants by feeding on roots, canes, primocane or floricane buds and thus affect plant health, vigor and/or yield. These insects and mites are discussed under the heading **Direct Pests.**

Harvest Contaminants

Many insects occur on raspberry plant foliage. Most of the insects and spiders are either innocuous or are beneficial because they eat other insects. However, when shaken off with the raspberries during machine harvesting, they become contaminants of the harvested product. The US Food and Drug Administration defect action level is "an average of four or more larvae per 500g or average of ten or more whole insects or equivalent per 500g (excluding thrips, aphids, and mites)". Food processors' standards are often more strict because of consumer pressure (23). Some insects can be removed by hand on the machine belt and the sorting belt in the processing plant, but this method is inefficient, costly, and prone to error. Harvesters are equipped with air suction fans, which help remove some plant and insect debris, but not all. Experiments with other air blasting equipment has helped but not solved this problem. Use of a "clean-up" insecticide spray just prior to harvest is a necessary supplement to these procedures (4). If uncontrolled, contamination of fruit can result in crop rejection. The key fruit contaminating insects are listed below beginning with the most commonly encountered and important pests.

Sprayer setup in raspberries.

Root Weevils

Black Vine Weevil, *Otiorhynchus sulcatus*
Rough Strawberry Root Weevil, *Otiorhynchus rugosostriatus*
Strawberry Root Weevil, *Otiorhynchus ovatus*

These three species of root weevils are the more commonly observed weevils prior to and during the raspberry harvest season. The life cycles are similar in that most of the population overwinter as grubs, feeding on roots in the top 2-8" of soil. Most pupate in April and emerge from the soil as adults during May and early June. These adults are active on foliage at night during June and July, feeding on aboveground plant parts. Newly emerged adults begin laying eggs in late June prior to the onset of harvest. It is the adult stage which coincides with harvest and is the most consistent and problematic fruit-contaminating insect on raspberries. These insects will crawl into the hollow center of the fruit and are not distinguishable to visual inspection. Species distribution varies from farm to farm, but the black vine weevil (BVW) tends to dominate. An insecticide (usually bifenthrin) is usually applied in late June prior to harvest and before egg laying begins in even lightly infested fields to prevent egg laying, buildup of weevils, and adult weevil contamination of the fruit (4). Routine monitoring using a beating tray[1] from mid-May through late June is a useful method to identify the species which are present and provide a rough estimate of population density before and after treatment. If left uncontrolled, losses include reduced vigor and yield from larval damage to roots, and crop rejection due to adult weevil contamination of fruit.

Control

Numerous biopesticides alone and in combination were field-tested in Whatcom County for controlling BVW larvae, but unfortunately none offered any significant level of control (15). Biopesticides which were tested in 1996 by WSU researchers included commercially available entomopathogenic nematodes, *Steinernema carpocapsae* (Biosafe) and 2 strains of *Heterorhabdites bacteriophora* (Bioxcel and Cruiser), and a new species isolated by Oregon State University (OSU), *H. marelatus*. The entomopathogenic fungus, *Beauveria bassiana* (Mycotrol) was also tested. Several species

[1] Scouting tool that is used to collect, identify, and count insects which are dislodged from the canopy.

of ground beetles (Family: Carabidae) are found in association with root weevil larvae in the soil and detected in the raspberry canopy but they do not provide economic control (8).

Bifenthrin (Brigade WSB, 0.1 lb. ai/acre). 3 day PHI. Brigade (Section 18) is the most effective and commonly used insecticide for root weevil control prior to harvest. Under this Emergency Exemption, a maximum of 0.1 lb. ai/acre per application is recommended and no more than two applications are allowed per season. It is usually applied after bees are removed, to avoid bee toxicity, and 3 to 4 days before harvest begins. Recent research has shown adequate root weevil control when the spray is directed to the lower 3 feet of the canopy compared to an entire canopy spray. This enables growers to achieve good weevil control with reduced amount of pesticide per acre. However, this basal spray technique has not replaced full canopy Brigade sprays which provide improved control of other insects and spiders which reside in the canopy and can contaminate fruit when machine-harvested. This annually updated Section 18 is usually not granted until May and typically expires in mid-August. There are efforts underway to pursue a full registration for Brigade on raspberries. This material applied as a pre-harvest "clean-up" spray provides the mainstay for raspberry growers, enabling them to produce and deliver acceptable, largely insect-free raspberry fruit. It has the added advantage of providing suppression of spider mites with minimal disruption of the naturally occurring predatory mite, *Amblyseius fallacis.* It is the most valuable insecticide used by raspberry growers and compliments existing IPM programs. If unavailable, quality of fruit would deteriorate and growers would be forced to make multiple applications of other less effective materials, which are more disruptive of spider mites, necessitating additional miticide applications as well. Yield would also decline, because alternative, effective insecticides, such as esfenvalerate require earlier bee removal and therefore reduced pollination and fruit set.

Malathion(1.5 to 2 lb. ai/acre). 1 day PHI. Occasionally used prior to harvest as a full canopy "clean up" spray, but does not provide satisfactory weevil control in most situations nor broad spectrum control of insect fruit contaminants, particularly worms. It is undesirable for use during bloom due to bee toxicity. Recent experience indicates potential for spider mite flare-ups following malathion use (13). Its short PHI makes it a preferred material for controlling aphids, when necessary, during the harvest period. For this reason, particularly, it is an important supplement to bifenthrin.

Azinphos Methyl (Guthion 50WP, 0.5 lb. ai/acre). 3 day PHI. Occasionally used as a pre-bloom hill drench in the row to control early-emerging adult root weevils, but timing is critical for effective control. Due to the extended period of weevil emergence from the soil, this application will only control a portion of the population. It is not recommended during bloom or before harvest due to bee toxicity (5). An important supplement to bifenthrin as a resistance management tool, targeting newly emerged soft-shelled adults as they emerge from the soil.

Cryolite (Gowan cryolite bait (20%), 8 lb. ai/acre). (24c-WA950018). 3 day PHI. This stomach insecticide is applied as a broadcast bait in an approximate 3-foot-wide band in the row. There has been limited grower experience with this product, but it has performed well (80% adult black vine weevil control compared to untreated check) in research conducted by WSU. Grower use patterns are therefore not established, but this material should prove useful for spring applications to partially control overwintering and summer emerging adult root weevils prior to the onset of egg laying. Effectiveness is limited in wet weather due to molding and destruction of the bait, which results in leaching and loss of the active ingredient (22). It will not provide enough control to insure weevil-free fruit during harvest, but is potentially a good supplement to contact insecticides and should fit well with the IPM program. The potential degree of control that may be realized with this material (80%) is inferior to the performance of the currently preferred material (bifenthrin), and is not acceptable as a sole strategy to control harvest contaminating weevils.

Esfenvalerate (Asana XL 0.025- 0.05 lb. ai/acre). (24c-WA950001). 7 day PHI. Registered but not recommended for use on raspberries due to its tendency to aggravate spider mite problems, bee toxicity, and impractical due to its small window for use (not earlier than 12 days before harvest and no later than 7 day before harvest). At least a week of pollination would be lost due to the need to remove bees before application (12).

Miscellaneous Caterpillars

Speckled Green Fruitworm, *Orthosia hibisci*
Raspberry Looper, *Autographa ampla*
Zebra Caterpillar, *Melanchra picta*
Bertha Armyworm, *Mamestra configurata*

These are the most commonly seen lepidopteran (butterfly and moth) pests on raspberries. They have either one or two broods of caterpillars per year (depending on the species) but the larval stage of each of these pests can coincide with harvest. For this reason, they pose a serious threat as fruit contaminants, being knocked from the foliage during the harvesting operation. Direct feeding on plant leaves in and of itself rarely justifies chemical control. Scouting, using a beating tray or by examination of foliar feeding has not proven to be effective in predicting the likelihood of significant caterpillar hatches and fruit contamination problems in most cases. However, preharvest leafroller evaluations can be useful in detecting hatch of bertha armyworms and need for treatment(8). If uncontrolled, contamination of fruit can result in crop rejection.

Control

Bacillus thuringiensis (Dipel, MVP, Javelin, Agree). 0 day PHI. Some control of these pests is incidentally achieved with 2-3 pre-bloom and bloom period sprays targeting various worms and leafrollers. Because timing is critical with this material and life stages of these pests are not synchronized, only partial worm control is typically achieved with this product. Bifenthrin, when applied before harvest, usually controls these pests adequately during the harvest period. However, Bt when used properly in combination with extensive scouting is an important biorational supplement for worm suppression, particularly in fields which are hand-picked for fresh market sales.

Western Raspberry Fruitworm

Byturus bakeri

Overwintering fruitworm beetles emerge from the soil during April and May. These small brown beetles feed on fruit buds and unfolding leaves during the early season, mate and then lay their eggs attaching them to flower buds and within opening flowers. The emergent young larvae work into the center of the developing young fruits where they feed for 30 days or more. Larvae can contaminate and downgrade machine harvested fruit (4). Adult populations are monitored by direct examination of the earliest open flowers and/or with a beating tray from mid-April through early bloom. A specific pattern of damage to foliage is also used to confirm presence of adult fruitworm beetles. The economic threshold for this insect is very low due to its direct damage to flower buds, resultant misshapen fruit, and potential for fruit contamination(7). Where scouting indicates presence of the insect in a field, an insecticide is applied to control adults prior to egg laying and before bees are introduced for pollination.

Control

Diazinon (Diazinon 4, 1 lb. ai/acre). 7 day PHI. Diazinon is the material of choice for fruitworm control. One application in mid-May, prior to the introduction of bees at the onset of bloom appears to provide adequate fruitworm control (8). It is applied as a foliar spray to the raspberry canopy. Most of the acreage destined for the processing markets (70%) vs juice markets (30%) is treated to control fruitworm (25). Provides some control of leafrollers and cutworms. Without treatment, an estimated half of the acreage would have fruitworm-contaminated fruit leading to crop rejection or shift to lower grade markets.

Leafrollers

Obliquebanded Leafroller, *Choristoneura rosaceana*
Orange Tortrix, *Argyrotaenia citrana*

Various species of leafroller larvae web and feed on raspberry foliage. This damage in itself is rarely economic, but larvae, if not controlled prior to harvest, can contaminate hand-picked and machine harvested fruit. The insect overwinters as a larva usually within protected old foliage or cane bundles in the field. In the spring the larvae move out to feed on developing foliage, pupate and emerge as adult moths. There are usually 2-3 generations per season. Obliquebanded leafroller (OBLR) is the dominant species in Whatcom County, whereas Orange Tortrix (OT) dominates in Skagit and the other southern counties. Life cycles of these two key species are quite similar, although OT poses a greater threat because hatch of the first summer brood of larvae is more likely to coincide with harvest and therefore contaminate fruit. Pheromone traps are used to monitor adult leafroller flight, but there is weak correlation between trap catch and larval infestation. Traps are used to identify peak flight. Fields are then scouted 10 days after peak flight (usually 2 weeks before harvest) to evaluate the degree of foliar infestation in order to determine if chemical treatment is necessary. If scouting shows 10% or more infested hills, treatment is usually warranted (7,10).

Control

Parasitoids contribute to the biological control of both species of leafrollers. In a 1993 study conducted in the lower Fraser Valley (British Columbia, Canada), parasitoids accounted for the natural mortality of 8% of caterpillars collected from the field (9). Other estimates in southern Washington and Oregon indicate field parasitism rates of OT ranging from 20 to 66% (14). Parasitism levels of overwintering OT larvae have been estimated as high as 60% (11). Recent field releases of *Trichogramma spp*. to control OT in Oregon and southern Washington have proven ineffective. Work is currently planned to evaluate other biological agents for leafroller control (14).

Bacillus thuringiensis (Dipel, MVP, Javelin, Agree). 0 day PHI. Several formulations of Bt are registered for and effective against leafrollers. Two applications approximately 10 days apart are necessary to provide adequate control. Proper timing and favorable weather conditions are critical for effective control due to variations in the susceptibility of different larval stages to this toxin and rapid photo-degradation of the material (9). It is an important biorational supplement for leafroller control, particularly in hand-picked, fresh market acreage.

Malathion (1.5 to 2 lb. ai/acre). 1 day PHI. This material is registered but poses a hazard to bees and is only compatible if larvae are in a susceptible stage after bees are removed and just prior to harvest. In this situation, bifenthrin (Section 18), which is the preferred material for controlling root weevils provides superior leafroller control as well.

Azinphos Methyl (Guthion, 0.25 lb. ai/acre). 14 day PHI. Should be applied no later than 2 weeks prior to anticipated bloom. High toxicity to bees and potential for spider mite disruption limit its use for leafroller control.

Carbaryl (Sevin, 2lb. ai/acre). 7 day PHI. Should be applied no later than 2 weeks prior to anticipated bloom. High toxicity to bees and potential for spider mite disruption limit its use for leafroller control.

Esfenvalerate (Asana XL, 0.025- 0.05 lb. ai/acre). (24c-WA950001). 7 day PHI. Registered but not recommended for use on raspberries due to its tendency to aggravate spider mite problems, bee toxicity, and impractical due to its small window for use (not earlier than 12 days before harvest and no later than 7 day before harvest). At least a week of pollination would be lost due to the need to remove bees before application (12).

Other Most Common Insect Contaminants in Machine-Harvested Raspberries

Raspberry Aphid, *Amphorophora agathonica*
European Earwig, *Forficula auricularia*
Various Stink Bugs (Family:Penatomidae)
Lygus Bugs (Family: Miridae)
Spiders

Control

Bifenthrin (Brigade WSB, 0.1 lb. ai/acre). 3 day PHI. Brigade (Section 18) is the most effective and commonly used insecticide for controlling insect and spider contaminants prior to harvest. Used primarily as a full canopy foliar spray delivered in a minimum of 100 gallons of water per acre. Applications are often made in the evening to maximize control of the key target pest; adult root weevils.

Malathion (1.5 to 2 lb. ai/acre). 1 day PHI. Effective against most harvest contaminants with the exception of adult root weevils and many species of cutworms and armyworms. Its short PHI makes it a suitable material once harvest is underway for controlling most other insect contaminants. Recent field studies indicate that it may aggravate spider mite populations (13).

Slugs

Slugs can be a fruit contamination problem. Usually associated with wet weather, slugs can climb up into the lower raspberry canopy where they are knocked from the plant during machine harvesting.

Control

Metaldehyde, (various bait formulations, 3-4% ai). This bait is scattered around the base of plants, applied as a band treatment to the row prior to harvest. It is used only on an as-needed basis when weather conditions are favorable and slugs are present. Usually one application is satisfactory. This is the only material available for slug control.

Direct Pests

Clay Colored Weevil

Otiorhynchus singularis

Adult clay weevils begin emerging from the soil in mid-March. They feed on developing buds, and new shoots with peak damage occurring in late March and April. Damage is similar to that caused by climbing cutworms. When numerous, this insect causes significant yield loss. 17% theoretical yield loss was estimated in 1998 field trials (6), but actual yield impacts are probably higher in heavily infested fields. This insect is becoming more widespread, and requires timely control when found to avoid yield loss and to deter population increase. Early season examination of damage to buds and new growth, combined with evening field monitoring using a beating tray are appropriate methods to monitor this insect (7). At the present time, there are no fully registered materials which provide adequate clay weevil control.

Control

Bifenthrin, (Brigade WSB, 0.05 to 0.1 lb. ai/acre) 3 day PHI. In April, 1998, the state of Washington granted a Crisis Exemption for Brigade to control excessive populations and reduce damage that was underway by this insect in some fields. This temporary registration provided a timely solution during the 1998 season. WSU trials (1998) showed that Brigade provided superior clay weevil control compared to other insecticides, when used either as a full canopy or basal spray (directed to the lower 3 feet of the plant) (6). Bifenthrin (Section 18) has become the standard broad-spectrum insecticide used before harvest (usually in late

June) to control other root weevil species and numerous fruit contaminating insects. Under the typical Section 18 registration schedule, it is not available when the clay weevil damage is occurring. A full registration for Brigade is being pursued.

Cryolite (Gowan cryolite bait (20%), 8 lb. ai/acre). (24c-WA980018). 3 day PHI. This stomach insecticide is available as a broadcast bait in an approximate 3 ft. wide band in the row. There has been limited grower experience with this product, (1998 24c) but it has performed well (80% adult black vine weevil control compared to untreated check) in research conducted by WSU. Grower use patterns are therefore not established, but this material may prove useful for early spring (late March, early April) applications to control emerging adult weevils. If effective, it would compliment an IPM approach. Effectiveness is limited in wet weather due to molding and destruction of the bait, which results in leaching and loss of the active ingredient. (22).

Malathion (1.5 to 2 lb. ai/acre). 1 day PHI. Available as a foliar spray for early season adult root weevil control, but is ineffective, particularly for clay weevil (19). Has potential to aggravate spider mite problems as well.

Azinphos Methyl (Guthion 50WP, 0.5 lb. ai/acre). 3 day PHI. Available as a pre-bloom soil drench in the row, to control emerging adult root weevils. It performed poorly in WSU trials during the 1998 season when used as a foliar spray targeting adult clay weevils in the canopy (6). Growers who have experimented with this material as either a soil drench or foliar spray report poor control (19). It would be used by growers as a last resort when necessary, in the absence of other registered and more effective materials.

Raspberry Crown Borer

Pennisetia marginata

This sporadic pest has a two-year life cycle. Adult clear-winged moths are present from late July through early October. Eggs laid by these moths, hatch into small caterpillars which crawl down to the base of the canes where they form an overwintering cell in the side of the cane. They begin to feed in early March on cane buds around the plant crown. Feeding damage in canes and crowns can weaken plants and kill infested canes (7,12). Weak areas within a field can be checked for evidence of this insect. Infested areas often have uneven bud break in the spring, and spindly canes, which break off at ground level. This symptom is most likely noticed during winter cane pruning and tying (7). Populations can increase rapidly, requiring control if this pest is present. Due to its two-year life cycle, this pest must be treated for two consecutive seasons in order to achieve control.

Control

Diazinon (2 lb. ai/acre). 7 day PHI. Applied as a soil drench to the crown area banded in the row, between October and March. It usually requires one application for 2 consecutive years to control this insect when present (3,12). One half to 2/3 of the total acreage is treated annually (25).

Spotted Cutworm

Amathes c-nigrum

This is the most commonly detected, early season climbing cutworm. It overwinters as a partly grown larva, which begins to feed on developing primocane and floricane buds in late March and early April. Feeding on primary buds can reduce production by 50% in infested areas (4). There are two overlapping generations per season. The second-generation larva can be a harvest contaminant. This insect is an occasional pest, spotty in distribution and damage, but when found can seriously impact yield. Early season examination of buds for damage and evening inspection of fields to confirm pest identity are appropriate monitoring techniques.

Control

None of the currently registered insecticides are particularly effective for controlling overwintering spotted cutworm larvae. Fortunately, it rarely is numerous enough to warrant control in the early season.

Bacillus thuringiensis (Dipel and others). 0 day PHI. Not very effective for controlling overwintering larvae which feed on new developing buds, because these larger worms are not as susceptible, and there is a low tolerance for bud damage. The insect must consume treated leaves or buds in order to be killed by this biological pesticide. It is more appropriate for controlling small, second generation worms later in the season.

Azinphos Methyl (Guthion 50WP, 0.5 lb. ai/acre). 3 day PHI. Provides partial control of overwintering worms. May provide some leafroller control if present. The preferred insecticide for early season, pre-bloom, cutworm control.

Diazinon (1 lb. ai/acre). 7 day PHI. Provides partial control of overwintering worms. May provide some leafroller control if present. This is an option, but not the preferred material for early season cutworm control.

Carbaryl (Sevin, 2 lb. ai/acre). 7 day PHI. Provides partial control of overwintering worms. Potential to aggravate spider mites. May provide some leafroller control if present. This is registered but rarely used.

Spider Mites

Twospotted Spider Mite, *Tetranychus urticae*
Yellow Spider Mite, *Eotetranychus carpini borealis*

These are the two most prevalent species of plant-feeding spider mites which inhabit raspberry foliage. Both species feed on chlorophyll on the underside of leaves. Feeding damage reduces plant vigor and may cause leaves to drop prematurely contributing to potential for winter injury and subsequent yield loss. They overwinter as adult females within protected micro-habitats in raspberry fields. They begin to colonize the plants in the early summer, moving upward on the canes as the season advances. Populations usually increase through June, and July, with potential for rapid increase after harvest in mid to late August. In September, populations decline as a result of predation by natural enemies and migration of overwintering females from the raspberry plants to overwintering sites (4). Raspberries appear to tolerate significantly greater densities of yellow mite compared to twospotted mites. Rough treatment thresholds are 75 vs 25 mites/leaflet prior to September 1 for these species. Foliar symptoms associated with feeding are different with the two species, which helps in determining which is present. Most growers rely on intuitive evaluations based on the degree of foliar damage, vigor of the field, and time of the year when determining spray needs. Direct counts of spider mites and predators can also be taken in the field to establish population trends. If uncontrolled, excessive defoliation during and after harvest from heavy twospotted mite feeding can reduce yield 25% the following season (20).

Control

Good farming practices (timely irrigation, proper fertilization) which help maintain a vigorous planting can help to reduce the impacts of spider mite feeding, but in some cases must be supplemented with chemical control. Predators play a major role in suppressing spider mites. The most dependable, naturally occurring spider mite predator is a Phytoseiid mite, *Amblyseius fallacis*. Studies over the past few years in Whatcom County indicate that this predator increases in density in response to both yellow and twospotted populations, and in many situations is able to provide acceptable biological control during and after harvest. This is the period when spider mites are most likely to increase rapidly and damage raspberry foliage (8). Field releases of this predator (augmentation) have been attempted with little success (13). Factors which influence biological control of spider mites by this predatory mite are not well understood. Other spider mite predators include minute pirate bug (Family: Anthocoridae) and a small beetle called the spider mite destroyer, *Stethorus punctillum picipes*. Unfortunately, the latter which is a very effective mite predator, is very sensitive to bifenthrin, the most commonly used "clean-up" insecticide spray.

Fenbutatin oxide (Vendex 50WP, 1 lb. ai/acre). 3 day PHI. Applied anytime during the season when spider mites increase to intolerable levels. It is most likely to be used if spider mites increase well before harvest, which is atypical, or after harvest when populations can increase rapidly and temperatures are high enough (> 70F) for optimum control. Two applications, 7 to 10 days apart are usually needed to suppress a rapidly increasing population. It is impractical for use during harvest due to its 3 day PHI. **Recent testing has shown that twospotted mite populations are partially resistant to Vendex (8).**

Dicofol (Kelthane 35, 0.6 to 1.2 lb. ai/acre). 7 day PHI. (24c-WA900022). Although registered for use, **this material is rarely used due to its ineffectiveness, presumably due to resistance, and extended pre harvest interval.**

Diseases

Botrytis Cane and Fruit Rot

Botrytis cinerea

Very common fungus which causes fruit rot and primocane lesions. It overwinters as sclerotia on primocanes and as mycelia on dead leaves and mummified fruit. These overwintering structures produce spores beginning in the spring which infect blossoms. These early blossom infections remain inactive (latent) until fruit is nearly ripe. When conditions are favorable for fungal growth within the berry, the fungus sporulates on the berry surface (gray mold). These spores contribute to secondary infection of fruit, primocanes, and other above ground, green plant parts. The infection and spread of the disease is favored by high moisture (excessive rain) and poor drying conditions (humid, stagnant air) during the bloom and harvest periods. Infections on the primocanes allow the fungus to overwinter within the field. Due to the microscopic nature of the latent blossom infections, monitoring for this disease is impractical (7). Preventative fungicide sprays during the bloom period and various cultural practices are used to help suppress the disease. This disease can drastically reduce both fruit quality and yield and has led to major crop failure and lost revenue for numerous growers over the past two seasons (1997 & 1998). If uncontrolled, estimated yield losses can reach 30% (8).

Control

Until the past two years (1997 & 1998), fungicides have protected the crop from disease. With the very recent discovery of widespread *Botrytis* resistance to most of the commonly used fungicides (iprodione, vinclozolin, and benomyl) a greater focus will be placed on cultural practices to help reduce disease incidence. These will likely include alternative training techniques, reduced interval between picking, and possibly alterations in the nutritional program as supplements to chemical control. Resistance to fungicides in the Willamette Valley in Oregon was documented some years ago (28).

Captan (Captan 50WP, 1 to 2 lb. ai/acre). 3 day PHI. (24c-WA980002)) Applied 3 to 6 times either alone or as a tank mix with other fungicides during the pre-bloom and bloom periods for *Botrytis* and spur blight control (8). **Considering recently confirmed resistance to other fungicides, this material is very important.**

Iprodione (Rovral 4F, 0.5 to 1 lb. ai/acre). 0 day PHI. Applied 2 to 4 times during the bloom and early harvest period (8). Has activity against spur blight. Not typically used during harvest except when disease incidence and favorable weather conditions persist. It is a preferred material when necessary during harvest because of the 0 day PHI. Widespread *Botrytis* resistance to iprodione documented in 1998 (16).

Vinclozolin (Ronilan 4F, 0.5 to 1 lb. ai/acre). 9 day PHI. Applied occasionally as a substitute for Rovral during the bloom period. Does not control spur blight. *Botrytis* is also resistant to this material (16).

Benomyl (Benlate 50WP, 0.375 lb. ai/acre). 3 day PHI. Applied occasionally as a tank mix with either Captan, Rovral or Ronilan. Does not control spur blight but does have activity against cane blight. Recently confirmed (1998) *Botrytis* resistance to this material (16).

Spur Blight
Didymella applanata

This common fungal disease infects floricane leaves, primocane leaves, and causes primocane lesions which can damage buds. Damaged buds are predisposed to winter injury, potentially reducing yield the next season. The disease overwinters on infected primocanes. In the spring it produces both windblown and rain-splashed spores (7). Recent research has identified key infection periods and optimum timing of fungicide applications to control spur blight. Field rating systems have been developed to help growers roughly categorize disease incidence (8).

Control

Lime-sulfur (Sulforix). Single application (2 to 3 gals product/acre) applied during the delayed dormant stage (March) (5). Widely used for activity against overwintering stage of fungal pathogens. Recent on-farm research efforts (1997 and 1998) indicate that a delayed timing and reduced rate of application may provide improved suppression of both spur blight and yellow rust (8, 13).

Captan (Captan 50WP, 1 to 2 lb. ai/acre). 3 day PHI. (24c-WA980002). Applied 2 to 3 times for spur blight control, usually in combination with another fungicide prior to bloom and during bloom. Also helps prevent *Botrytis* fruit rot infection. Widely used as a protectant fungicide to control germinating spores.

Iprodione (Rovral 4F, 0.5 to 1 lb. ai/acre). 0 day PHI. Usually applied 2 times alone or with Captan for spur blight control. This same treatment helps prevent *Botrytis* fruit rot infection, which is the primary target. In spite of recently detected *Botrytis* resistance to this material, it may be an important supplement or alternative for spur blight control.

Yellow Rust
Phragmidium rubi-idaei

This fungus infects floricane and primocane foliage. In some years, it causes significant premature leaf death, reducing plant vigor and increasing the likelihood of winter cold injury. It overwinters in old primocane leaf debris trapped in bundles of canes where they are tied to the trellis wire. Spores from this debris cause the initial spring infection of floricane leaves, the first visible symptom of disease. Spores from these lesions allow the disease to spread further, ultimately giving rise to a repeating spore type which allows for continuous spread and development of the overwintering stage. Scouting early in the season and after harvest is recommended to assist with decision-making on sprays and need for cultural practices to reduce winter carryover (7).

Control

It is recommended that in infected fields, leaves be removed from primocanes before they are tied up in the fall, or that cane tying be delayed until after leaves have dropped. Then they are tilled into the soil. This sanitation practice is not always practical, but when used, it is the cornerstone of control (5). Delaying cane tying can be impractical for some growers for two reasons. Firstly, there is a ready supply of labor immediately after harvest and secondly, prompt training clears primocanes from between the rows which opens a clear path for tractor-drawn equipment (ripping soil, post-harvest sprays, cultivation, etc.). Premature leaf removal may reduce the amount of carbohydrates translocated from leaves to roots, which can weaken plants and may influence winter hardiness.

Lime-sulfur (Sulforix). Single application (2 to 3 gals product/acre) applied during the delayed dormant stage (March). This application also suppresses spur blight (5). Widely used for activity against overwintering stage of the disease. It is only partially effective because it can only be applied as a delayed dormant spray.

Carbamate (Ferbam, 1.14 lb. ai/acre). 40 day PHI. (24c-WA940029a). 1 to 2 applications, 14 days apart beginning usually in mid-April are applied by some growers. In 1998 WSU trials, 3 applications of this material provided only limited control of yellow rust (16).

Propiconazole (Orbit 3.6L, 0.1 to 0.17 lb. ai/acre). 30 day PHI. Section 18 Crisis exemption in 1998 expired 11/1/98. Minimal grower experience with material, but has activity against different stages of the pathogen, and 3 applications provided excellent control in 1998 WSU field trials (16). Use patterns not established, but label permits up to 5 applications season. The manufacturer will support another Section 18 request. This material looks very promising, performing better than those currently registered and used by growers.

Copper (Kocide 2000). Used occasionally by some growers as a supplement to Ferbam, particularly in diseased fields and within 40 days of harvest, when Ferbam can no longer be applied. In 1998 WSU trials, 3 applications of this material were ineffective for yellow rust control (16).

Bordeaux (hydrated lime plus copper sulfate) Applied by some growers after harvest and once pruning and tying are complete.

Cane Blight

Leptosphaeria coniothyrium

This fungus is a wound parasite and can only enter the plant through wounds. Physical damage to the surface of the primocanes (usually from machine-harvesting) allows the fungus to enter the vascular tissue. The fungus remains in the vicinity of the wound, but toxins produced by the fungus move up the cane, killing vascular tissue and buds. In infected canes, a reddish streaking lesion can be seen in the fall by scraping away the epidermis above primocane wounds. The disease overwinters on old cane stubble and infection is favored by wet conditions during the harvest period. Examination of suspect primocanes in the fall and early spring is recommended to confirm presence of this disease (7).

Control

Adjustment of catcher plates on harvesting machines can help to minimize primocane damage and reduce the likelihood for infection. Most growers make all possible adjustments to harvesting machines to minimize physical injury to the primocanes.

Benomyl (Benlate 50WP, 0.375 lb. ai/acre). 3 day PHI. 1 to 2 applications in infected fields usually directed at the lower portions of canes during and/or immediately after harvest is completed (5). Cane blight is not listed on the label but this use is consistent with that for *Botrytis* fruit rot. It is the only fungicide registered on raspberries with activity against this fungus.

Phytophthora Root Rot

Phytophthora fragariae var *rubi*

This soilborne fungus, favored by wet soil conditions, can directly invade and kill root and crown tissue. Aboveground symptoms include collapse of fruiting canes and wilting of primocanes. Diseased plants have fewer feeder roots and brown or black discolored root tissue. Infection and plant destruction is usually more common in low, wet areas within a field. Fields should be scouted during harvest for these symptoms, and where found, laboratory analysis of root tissue is recommended (7). If uncontrolled, with disease present and favorable conditions for infection, yield losses can reach 75% (21).

Control

Cultural practices to prevent infection include: avoidance of fields with history of the disease, planting only in well drained soils, ripping soil to improve soil drainage, ridging or planting into raised beds, cleaning cultivation equipment to avoid spread from infected to healthy fields, and use of certified root stock (7). With the exception of "cleaning cultivation equipment", these cultural practices are standard industry practices. No cultivars have acceptable levels of resistance.

Established Fields

Metalaxyl (Ridomil 0.50 lb. ai/acre). 45 day PHI. Usually applied once in the fall or early spring as a band soil treatment in the row. Some growers use split (half rate) applications at both times of the year. This is the preferred material for *Phytophthora* suppression and is standard practice in fields where the disease-causing organism has been detected. It is often applied at planting time in fields with a raspberry history, in order to protect young plants, which are particularly susceptible given their small root mass. In order to prevent the development of metalaxyl-resistant strains of *Phytophthora* over time, it is recommended that this material be used exclusively on an as-needed, rather than simply protectant basis.

Fosetyl-Al (Aliette). 60 day PHI. Applied as a foliar spray in the spring and after harvest. Four applications per season are needed, but WSU trials have shown it to be about 30% less effective than Ridomil for root rot control (5, 16). Not very regularly used.

Prior to Planting

Chloropicrin. Added to either 1,3 dichloropropene (Telone II) or to methyl bromide at average rate of 100 pounds per acre. It is applied as a pre-plant treatment to improve control of *Phytophthora*. Helps to delay onset of the disease for 1-4 years (5). This is a very important material, used in 95% of replanted fields and about 50% of first time plantings (24).

Metam Sodium (Metam, Vapam). Applied as a pre-plant treatment for suppressing soil disease organisms, including *Phytophthora* and plant parasitic nematodes. Use rates range from 50 to 100 lb. per acre. Helps to delay onset of disease (5). Limitation of this material is that it is difficult to adequately treat nematodes and disease organisms at soil depths much greater than 6 inches (24). Sometimes combined with Telone II to improve weed and soil disease control.

Nematodes

ROOT LESION
Pratylenchus penetrans
DAGGER
Xiphinema bakeri

Root lesion nematodes inhabit the soil and are capable of feeding on and migrating within raspberry roots. Damage associated with root lesion nematode feeding includes root destruction and a general reduction in field vigor over time. Dagger nematodes feed on root tips and in addition to directly damaging root tissue, are capable of transmitting the tomato ringspot virus, which can stunt raspberry plants and cause crumbly fruit, thus impacting both yield and fruit quality. Soil samples are collected before planting a field to aid in site selection and/or need for pre-plant fumigation. Soil and root samples collected in the fall from good and poor areas within established fields will help evaluate nematode density, species distribution, and need for treatment. Treatment threshold levels based on laboratory analysis are established for root lesion nematodes. Populations that exceed 250 nematodes/250 cu. cm. at planting will affect stand establishment, and populations exceeding 500 nematodes/250 cu. cm. will weaken established fields. As with most pests, the impact of nematodes on a vigorous field is less pronounced than on a weak field. Nematode damage may occur at lower nematode densities if plants also are stressed by root rotting diseases, insects, or other factors (27). Due to its capability to transmit virus, the threshold for dagger nematodes is very low and there are no materials registered for use in established fields to control this pest (7). If left uncontrolled, root lesion nematodes will shorten the productive life span of an established field by 2 to 3 years (25), and dagger nematodes if not treated prior to establishment in replant situations will weaken fields and reduce fruit quality and yield (3). Both species are widespread throughout the region.

Control

Keeping fields fallow and weed-free for a year prior to planting raspberries will reduce, but not eliminate nematode populations (5). Planting stock certified to be free from tomato ringspot virus on land which is free from dagger nematodes is advised but may be difficult to accomplish (3). Crop rotation is not an option since tomato ringspot has such a wide host range and dagger nematodes feed on so many hosts as well. A planting site need not have ever been in red raspberries before for Tomato ringspot virus to cause serious damage to a new (young) field.

Established Plantings

Fenamiphos (Nemacur 3, 3 to 6 lb. ai/acre). Root lesion-infested fields are usually treated every other year with a single soil application banded in the row between October 1 and December 31 (5). It is applied as a liquid in the fall when rain will carry it into the soil. This is the only currently registered nematicide for suppressing root lesion nematodes in established plantings. Unfortunately, it has no activity against dagger nematodes. Treatment is usually based on the results of soil samples taken in late summer. There are no viable alternatives for suppressing root lesion nematodes in established fields.

Prior to Planting

Methyl Bromide (Brom-O-Gas). Injected into the soil as a pre-plant fumigant for nematode control usually in the late summer or early fall in anticipation of spring planting. The usual rate is 200 lb. per acre. Combination with chloropicrin (100 lb. per acre) is the preferred pre-plant treatment for controlling nematodes and soil disease organisms in replant situations, where root rot diseases are more likely to pose a threat. Ninety-five percent of raspberry fields which are replanted are fumigated prior to planting. About half of new plantings with no history of raspberry production are fumigated before planting (17, 24). In some cases, usually when nematode or soil disease pressure is greater, treated fields are immediately covered with a plastic tarp, which seals in the fumigant.

OR:

1,3 dichloropropene (Telone II). Shanked into the soil at a rate of 18 to 25 lb. per acre, it is usually applied in the fall several months before planting. If soil disease requires treatment, and in replant situations, chloropicrin (100 lbs. per acre) is added to improve control. Either this combination or methyl bromide plus chloropicrin is used prior to planting in 95% of replant situations, and in about 50% of first-time raspberry plantings (24). Few new plantings are made on ground that has never been planted to raspberries.

(continued)

Weeds

Various species of weeds compete with raspberry plants for water and nutrients. In addition weeds can interfere with harvesting efficiency and reduce air movement, thus increasing the likelihood of cane, fruit and foliar diseases. Growers rely on a combination of chemical and cultural practices to manage weeds in their raspberry fields. Weeds within the rows are usually managed with banded herbicide applications, either pre- or post-emergent, and weeds between the rows are managed primarily by regular, frequent, shallow cultivation during the growing season. Raspberries respond to a non-disturbed, competition-free strip in the planted row. This is achieved through the application of directed, banded herbicides as well as primocane suppression materials (cane burning) usually applied once in the early spring (18). It is recommended that growers make it a practice to take note of shifts in predominant weed species which indicates development of resistance and the need to select alternative weed management strategies or materials (5).

Control

Shallow tillage between the rows using a rotary-type cultivator is the standard method for summer weed control. Although this operation is performed routinely during the growing season, care is taken to avoid excessive frequency since it can destroy soil structure, lead to soil compaction and increase root stress. Some growers plant winter cover crops between the rows in the late summer to compete with weeds, reduce erosion, and improve soil condition (5).

Weeds are controlled in areas immediately around fields primarily by maintaining year-round sod, which is mowed regularly during the growing season.

Pre-emergent herbicides

Diuron (Karmex DF, Direx 80DF, 1.6 to 2.4 lb. ai/acre). This pre-emergent herbicide can be applied to the row with either a single winter application or split applications in October and March. Usually it is applied in the spring. It is not recommended on soils which are very sandy or gravelly, or soils with less than 1% organic matter. Diuron is particularly effective against chickweed and redroot pigweed as well as most problem grass species with the exception of quackgrass. It is one of the three most commonly used pre-emergent herbicides.

Simazine (Princep, 1.6 to 4.0 lb. ai/acre). This pre-emergent herbicide can be applied to the row as a single winter application or split applications in October and March. It is often rotated with diuron to avoid weed shifts. Usually applied in the spring, it is one of the three most commonly used pre-emergent herbicides.

Oryzalin, (Surflan, 2.0 to 6.0 lb. ai/acre). This pre-emergent herbicide can be applied to the row in late fall or early spring. Usually applied in the spring, it is one of the three most commonly used pre-emergent herbicides.

Norflurazon, (Solicam, 1.97 to 3.93 lb. ai/acre). This pre-emergent herbicide can be applied to the row once per year from fall to early spring. It is primarily used where annual grass control is a problem but also has activity against several common broadleaved weeds.

Napropamide, (Devrinol, 4.0 lb. ai/acre). Occasionally used as a spring applied herbicide, but effectiveness is limited if not incorporated by rainfall within 2-3 days of application due to rapid photo-degradation. Performance is also reduced by excessive plant residue on soil surface.

Dichlobenil, (Casoron, 4.0 lb. ai/acre). Especially useful as a spot application in mid-winter to control perennial weeds (field horsetail, quackgrass, yellow nutsedge and canada thistle) which escape control from the other more commonly used pre-emergent herbicides.

Terbacil, (Sinbar, 0.8 to 1.6 lb. ai/acre). 70 day PHI. Occasionally used as a spring applied herbicide. Not recommended on gravelly soils or soils with less than 1% organic matter or within 2 years of a replant situation. It needs to be washed into the soil by rain or irrigation.

Post-emergent contact herbicides

Paraquat, (Gramoxone Extra, 0.625 to 0.94 lb. ai/acre). A contact herbicide applied to the row either in the late winter or the early spring before new primocanes emerge, or in late summer. May be mixed with some soil applied pre-emergent herbicides.

Sethoxydim, (Poast, 0.28 to 0.47 lb. ai/acre). 45 day PHI. Used to control established grasses. Major benefit of this material is quackgrass suppression.

Pronamide, (Kerb, 1.0 to 3.0 lb. ai/acre). A fall-applied herbicide to control grasses, including quackgrass.

Glyphosate, (Roundup, Honcho). A contact/systemic herbicide applied as a broadcast or spot treatment prior to planting raspberries. It is not registered for use on established plantings.

Nonbearing only, contact grass herbicides

Fluazifop-p-butyl, (Fusilade DX, 0.125 to 0.375lb. ai/acre). Can be used in the early summer up to 1 year prior to first harvest (until late June of planting year) for grass control. Provides good suppression of most common grasses including quackgrass.

Clethodim, (Prism, 0.095 to 0.176 lb. ai/acre). Provides good control of a broad spectrum of annual and perennial grasses including quackgrass.

Primocane suppression

It is standard practice for raspberry growers to burn back or suppress new shoots or primocanes in the spring. The primary benefits of cane burning are a reduction in cane size to a size which is more favorable for machine harvesting, and the overall suppression of numerous fungi which cause diseases of leaves, fruit and canes. One spray is usually applied to the row when the first flush of primocanes is about 6" tall. Cane burning may not be practiced in older, weaker fields because they are less likely to produce a second vigorous flush of primocanes which are necessary for sustaining production (3).

Control

Oxyfluorfen, (Goal 2XL, 0.05 to 0.1 lb. ai/acre). (24c -WA960005). This material is applied to the rows for early season suppression of primocanes when they are 4-6" tall. It also provides some contact weed control. This is currently (1998) the material of choice and is standard practice in the industry. If not available, a percentage of growers would switch to propane flaming which is dangerous to the applicator and a much less selective method, likely resulting in excessive damage to both primocanes and floricanes, reduced yield, and increased labor expenses.

Monocarbamide dihydrogensulfate, (Enquik, 10 to 15 gals of product). (24c-WA890009). This material was registered to provide an alternative to oxyfluorfen, but is rarely used because it is very corrosive and can damage sprayer fittings. In addition, cane burn is not as quick nor as complete. It tends to produce "cripples", or canes that have multiple leaders with distorted growth. The second flush of primocanes often develops too early after treatment and the material adds nitrogen to a field which often is not needed nor desirable (25).

Estimates of Pesticide Usage and Representative Spray Program

The following two tables are included in order to provide a more complete understanding of key chemicals and usage patterns (Table 1), as well as a typical pesticide program for the year in an established raspberry field on a farm which is targeting higher-end/higher-value markets (Table 2). Farms targeting the lower-end juice market would apply about half of the fungicide applications shown in this table. As the text spells out, some of these treatments are not needed nor used every year.

Table 1

Estimate of Usage of the Most Common Pesticides* in Raspberries in Washington State During the 1997 crop year

Pesticide	% Area treated	# Applications per year	Lb. AI/acre per application	Lb. AI/ treated acre per season
Insecticides				
»Bifenthrin**	81	1.0	0.10	0.10
Bt	46	2.1		
»Diazinon	77	1.4	1.10	1.54
Esfenvalerate	36	1.0	0.06	0.06
»Malathion	44	1.0	1.07	1.07
Fungicides				
»Benomyl	76	1.7	0.49	0.83
»Captan	94	5.0	1.17	5.85
Ferbam	61	1.3	1.23	1.60
Iprodione	71	1.3	0.60	0.78
»Lime Sulfur	70	1.0	9.16	9.16
»Metalaxyl	49	1.2	0.49	0.59
Vinclozolin	58	2.6	0.54	1.40
Herbicides * **				
»Diuron	31	1.0	0.97	0.97
Norflurazon	4	1.0	1.20	1.20
»Oryzalin	62	1.0	1.20	1.20
»Oxyfluorfen	74	1.0	0.10	0.10
»Paraquat	85	1.1	0.32	0.35
Sethoxydim	5	1.0	0.19	0.19
»Simazine	56	1.1	0.62	0.68

Source: Adapted from the National Agriculture Statistics Service, USDA Pesticide Data Program, Fruit summary for the 1997 Crop Year. URL: http://www.usda.gov/nass/pubs/estindx1.htm#agchem

*** Limited to pesticides used to control insects, diseases, and weeds only.**

**** Materials shown in red or marked with this symbol (») are heavily relied upon and have few or no currently registered and effective substitutes.**

***** Discrepancies in rates between this table and text in the weed control section are due to different methods of reporting. The text shows labelled rates per acre. Because these materials are typically applied in 3-4 ft. wide bands in the row, actual use per acre is 30-40% of the labelled/broadcast rate as shown here.**

Table 2

Typical Pesticide Spray Program for the Year On an Average Farm[2]

Date	Pesticide	Lbs AI/acre	Method	Target Pest*	Crop Stage
March	Diazinon	2.0	Banded	Crown borer	Dormant
	Diuron	1.6-2.4	Banded	Weeds	Dormant
	Metalaxyl	0.5	Banded	Root rot	Dormant
Late March	Lime Sulfur	9	Foliar	Cane diseases	Delayed dorm.
Early April	Oxyfluorfen	0.1	Directed base	Cane burn	Pre-bloom
Early May	Captan	2.0	Foliar	SB	Pre-bloom
Mid May	Captan	2.0	Foliar	SB	Early Bloom
	Iprodione	0.5	Foliar	Botrytis, SB	Early Bloom
	Diazinon	1.0	Foliar	Fruitworm	Early Bloom
Late May	Captan	2.0	Foliar	Botrytis, SB	Bloom
Early June	Captan	2.0	Foliar	Botrytis, SB	Bloom
	Vinclozolin	0.5	Foliar	Botrytis	Bloom
Mid June	Captan	2.0	Foliar	Botrytis, SB	Bloom
Late June	Captan	2.0	Foliar	Botrytis, SB	Pre-Harvest
	Iprodione	0.5	Foliar	Botrytis, SB	Pre-Harvest
	Bifenthrin	0.1	Foliar	Insects	Pre-Harvest
August	Benomyl	0.375	Foliar	Cane blight	Post-Harvest
	Fenbut. Oxide	1.0	Foliar	Spider Mites	Post-Harvest
October/Nov	Fenamiphos	6.0	Banded	Nematodes	Post-Harvest

Source: WSU Vancouver, Lynden Satellite Station IPM Project (1998) and personal communication with raspberry growers.

*** Target pest codes where abbreviated:**

Crown borer: Raspberry Crown Borer, *Pennisetia marginata*
Root rot: primary target is *Phytophthora fragariae* **var** *rubi*
Cane burn: Primocane suppression
SB: Spur Blight, *Didymella applanata*
Botrytis: Gray mold fruit rot; *Botrytis cinerea*
Insects: Adult root weevils and miscellaneous harvest- contaminating insects and spiders
Nematodes: Root Lesion Nematodes, *Pratylenchus* **spp.**

[2] Spray programs vary between farms and between years in frequency, selection, and timing of applications. This program does not show all pesticides options in this crop.

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