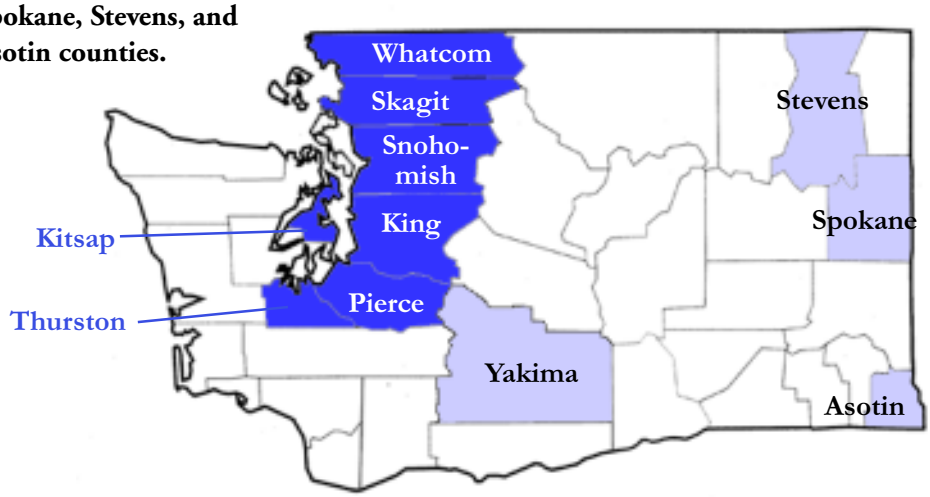
Crop Profile for
Bedding Plants
in Washington

Production Facts

- Bedding plants make up 26% of total gross sales for the plant industry in Washington State ("plant industry" defined here as live nursery goods, bulbs, fruit trees, cut flowers, grass seed and sod, hard goods, and services) (2).
- Annual gross sales from bedding plants in Washington State, during 1996-97, were $219,132,769 (2).
- Wholesale values of potted flowering plants and bedding/garden plants in Washington were $69,763,000 in 1999 ($10,277,000 and $59,174,000, respectively) (1).
- Washington State's bedding plant industry consists of small to large greenhouse operations ranging in size from 5,000 to 400,000 square feet of greenhouse space.

Production Regions

Most bedding plant production in Washington takes place west of the Cascade Mountains, primarily in King, Kitsap, Pierce, Skagit, Snohomish, Thurston, and Whatcom counties, with a few small greenhouses in other western Washington counties. Several greenhouses exist in eastern Washington in Yakima, Spokane, Stevens, and Asotin counties.



General Information

Bedding plants include a large number of annual and perennial plant species that provide seasonal color in the landscape and in hanging baskets (Table 1, page 3). The largest consumer of bedding plants is the general public, the second largest is landscape companies.

It is difficult to strictly define bedding plants because annuals and perennials are grown in the same greenhouses and are sold and shipped together. Plant types and production systems are numerous and diverse. Rather than attempt to completely detail all types and systems in this report, descriptions are confined to commonly performed practices, prevalent systems, and plants produced in the largest quantity.

Bedding plants are sold to wholesale and local and national retail outlets and landscape companies. The market division (wholesale-to-retail ratio) varies tremendously among businesses. The larger businesses and a few of the small businesses primarily sell wholesale. Most of the small and medium-size businesses sell portions of the crop at wholesale and portions at retail. A few smaller greenhouse businesses primarily grow plants that are sold through their own retail outlet.

Forty-eight commercial (wholesale/retail) greenhouse businesses belong to the Washington Floricultural Association and Puget Sound Flower Growers Association. Supply businesses, community colleges, and parks are also members of these associations but not counted in this profile as they are not commercial bedding and flowering plant producers.

Cultural Practices

This report emphasizes greenhouse production systems. Greenhouse production systems are unique in that relatively high value crops are grown throughout the year. Greenhouse structures include glass, transparent fiberglass, transparent polycarbonate, and polyethylene covered structures on metal, wood, and PVC pipe frames. Some large and mid-sized operations have houses with retractable roofs.

Bedding and flowering potted plants are propagated both by seed and cutting.

Seeding can be done by hand, but is mostly done with an automated seeder, either a rotating drum shaker or a negative pressure seed selector that places one seed per plug in a tray. The trays are typically 10.75 x 21.25-inch rectangles and each contains 72 to 800 wells (plugs). Prior to seeding, plugs are filled with a fine-grade peat that may have had the pH lowered to 4.5. Production of plugs from seed takes approximately 10 to 14 weeks, but can take longer with some plant species.

Stock plants are used as the source of cuttings. Upon removal, cuttings are bundled and stored for less than one week. Cuttings are often dipped in or sprayed with a disinfectant then stuck in a fine-grade peat and vermiculite or perlite mixture in trays that contain 18 to 48 plugs. Tray sizes for propagating cuttings vary, ranging up to 17 inches square. Rooting takes approximately 6 to 10 weeks.

Whether produced from seed or cutting, plugs are intermediate products that can be sold to other businesses or used by the same business to repot and produce larger plants. Plants grown in a smaller-sized plug (higher number of plugs per tray) are replanted in larger-sized plugs or pots (3.5 to 10 inches in diameter) in a medium-grade peat that contains vermiculite or perlite. Larger-size plugs (e.g., 18 plugs per flat) may be sold directly to consumers. At the later stage of production, some flats or pots of plants will be grown outside on polyethylene ground fabric. This increases production area and allows plants to become acclimated to outdoor environmental conditions before being sold to consumers. This process of acclimation is known as “hardening off.”

The following information on pest problems was acquired by interviewing business owners or production managers in summer 2000; from plant disease clinic records (1997, 1998, 1999) at the Washington State University Puyallup Research and Extension Center; from a 1993 entomology greenhouse survey; and through author observations. Owners or production managers of eight greenhouses were interviewed to compile the information contained in this report. Personal interviews were used in lieu of a mailed survey to pro-

vide comprehensive detail. Most interviews were preceded by recording information directly from pesticide spray records, then interviewing the manager about company practices. An on-site visit allowed an assessment of the facilities and observation of the operations and current level of pest problems.

The summary of pest control measures in this report strictly represents the production end of bedding plants. This includes businesses that sell wholesale to finish growers and retail outlets, and those that sell wholesale and have a retail division. Businesses that are strictly retail, such as garden and floral shops, and drug, grocery, hardware, and discount department stores, were not included because they are geared towards short retention, therefore implement limited use of control measures. Control measures applied in landscape businesses were not included.

Of the pest problems, insects were the most damaging pests, followed by diseases, then weeds and other pests.

TABLE 1

A representative list of annual and perennial bedding and flowering plants (twenty-nine plant families and eighty-two genera) commonly produced in Washington. Genera are listed under respective family names and select common names are in parentheses.

Amaranthaceae	**Boraginaceae**	**Lamiaceae**	**Saxifragaceae**
Celosia	Myosotis (forget-me-not)	Coleus	Astilbe (spirea)
Apocynaceae	**Brassicaceae**	Salvia (sage)	Bergenia
Vinca (periwinkle)	Arabis (rockcress)	Stachys (betony)	Heuchera (coral bells)
Asteraceae	Aubrieta (rockcress)	**Onagraceae**	**Scrophulariaceae**
Achillea (yarrow)	Aurinia (basket-of-gold)	Clarkia	Antirrhinum (snapdragon)
Ageratum	Erysimum (wallflower)	Fuchsia	Bacopa
Artemisia	Iberis (candytuft)	Godetia	Calceolaria (pocketbook plant)
Aster	Lobularia (alyssum)	**Papaveraceae**	Digitalis (foxglove)
Bellis (daisy)	Matthiola (stock)	Papaver (poppy)	Linaria (toadflax)
Callistephus (aster)	**Campanulaceae**	**Plumbaginaceae**	Mimulus (monkey flower)
Centaurea (bachelor button)	Campanula (bell flower)	Armeria (thrift)	Nemesia
Chrysanthemum	Lobelia	Limonium (statice)	Torenia
Coreopsis	**Capparidaceae**	**Polemoniaceae**	**Solanaceae**
Cosmos	Cleome	Phlox	Browallia
Dahlia	**Caryophyllaceae**	Polemonium (Jacob's ladder)	Nicotiana (ornamental tobacco)
Dimorphotheca (African daisy)	Arenaria (moss sandwort)	**Portulacaceae**	Petunia
Doronicum (bane)	Cerastium (snow-in-summer)	Portulaca	Salpiglossis (painted tongue)
Gaillardia (blanket flower)	Dianthus (carnation)	**Primulaceae**	Schizanthus (butterfly flower)
Rudbeckia (coneflower)	Gypsophila (baby's breath)	Primula (primrose)	**Tropaeolaceae**
Tagetes (marigold)	Saponaria (soapwort)	**Ranunculaceae**	Tropaeolum (nasturtium)
Veronica (ironweed)	**Convolvulaceae**	Anemone	**Valerianaceae**
Zinnia	Ipomoea (morning glory, sweet potato)	Aquilegia (columbine)	Centranthus (Valerian)
Balsaminaceae	**Dipsacaceae**	Delphinium	**Verbenaceae**
Impatiens	Dipsacus (teasel)	Nigella	Verbena
Begoniaceae	Scabiosa (pincushion flower)	Ranunculus (buttercup)	**Violaceae**
Begonia, fibrous	**Geraniaceae**	**Rutaceae**	Viola (pansy, violet)
Begonia, tuberous	Pelargonium (geranium)	Ruta (rue)	

Insects/Mites

Insect damage can cause loss in revenue in several ways. When plants have visible damage from insects (blemishes, poor size or bloom characteristics, dead tissue), they fail to meet market criteria and do not generate revenue. (No attempt was made in this profile to quantify the value of plants discarded or devalued due to insect damage.)

Excessive pest control costs can also negatively impact revenue. The level and frequency of pest control is typically based on the severity and/or frequency of pest damage and the value of the crop. The price of ornamental plants is directly related to the plants' physical appearance. Pest control is implemented to prevent visual damage and death, and it is also necessary to achieve marketable growth attributes in a specified time period. Slow growth or a need to promote new growth to compensate for damaged tissue can result in plants being unavailable during high demand periods. Demand is associated with seasonal holidays and favorable climate during spring and fall periods. Price and volume of sales are directly related to these windows of opportunity and the continued success of ornamental businesses that deal with bedding and flowering plants. Delaying production by one or more weeks can significantly reduce returns.

Based on a 1993 survey, aphids, spider mites, fungus gnats, and thrips were the most common greenhouse pests in Washington. These pests were reported by 70%, 49%, 23%, and 21% of the growers, respectively (9). The level of damage or control difficulty in order of most to least severe was thrips, fungus gnats, aphids, and spider mites. During the current survey, some businesses listed aphids as the most severe insect problem. Other pest insects identified during the interviews included beetles, caterpillars (larvae), leafhoppers, and whiteflies.

Thrips can cause yellow, bronze, or brown flecking or can deform plant parts (e.g., cause curling of leaves). Aphid feeding stunts plant growth and causes curling and puckering of expanding flowers and leaves. Mites cause white, yellow, red, bronze, or brown flecking over foliage and flowers; severe damage will reduce overall growth. In addition, spider mites attach thin webbing between plant parts. If mites are present, they may crawl on humans that handle the plant and cause itching that results in consumer complaints. Feeding by whiteflies can stunt plant growth and cause wilting. The presence of whiteflies is visually unacceptable to knowledgeable consumers even when no damage has manifested. Beetles and caterpillars chew holes in leaf tissue, which is unsightly and can cause poor growth due to epidermal and vascular tissue damage.

All insects listed in this report occur on more plants than the few given as examples. The plant species listed were the ones emphasized by those interviewed in the survey. Thrips were reported on candytuft, geranium, impatien, and perennial daisy. Fungus gnats were reported on *Fuchsia* spp., *Gallium* spp., and

TABLE 2

Insect pests of bedding and flowering plants in Washington and the pesticides used as reported in a 1993 survey.

Pest	Chemicals
aphid	Astro, Azatin 3, BotaniGard ES, Cinnamite, DuraGuard 20, Endeavor, Enstar II, Lannate LV 29, Marathon 60, Mavrik, M-Pede, Orthene 75, Pinpoint 15, Py-Rin (GS-5), Sunspray Oil 11E/6E, Tame 31, Thiodan 50WP, Topcide 10
spider mite	Avid, Cinnamite; Duraguard 20, Dursban 50W, Marathon 60, M-Pede, Orthene 75, Sanmite, Talstar GH, Topcide 10
fungus gnat larvae	Adept, Azatin 3, Citation 75, Distance, Duraguard 20, Enstar II, Gnatrol, Precision WP
fungus gnat adult	M-Pede, Talstar GH
thrip	Conserve, Duraguard 20, Dursban 50W, Marathon 60, Mavrik, M-Pede, Orthene 75, Precision WP, Py-rin, Talstar GH, Topcide 10, Turcam 76
mealybugs	Enstar II 65, Marathon 60, M-Pede, Talstar GH, Topcide 10
beetle	Astro, Dursban 50W, Mavrik, Talstar GH, Thiodan 50WP
caterpillar	Orthene 75, MVP II
whitefly	Adept 25, Avid, Azatin, Enstar II 65, Marathon 60, Mavrik, M-Pede, Precision WP, Sanmite, Talstar GH, Tame 31, Thiodan 50WP, Topside 10, Turcam 76
root maggot	Astro, DuraGuard 20, Marathon 60, Turcam 76

Viola spp. Aphids were reported on *Aster* spp., *Begonia* spp., chrysanthemum, *Cosmos* spp., *Echinacea* sp., geranium, phlox, ornamental kale, ornamental pepper, *Viola* spp., and sweet potato. Spider mites were reported on *Crocosima* spp. and *Viola* spp. Mites were reported as a problem but no list of plant species was generated. Whitefly was not a severe problem but was reported. Beetles occurred incidentally on several hosts, but were noted to be problematic on *Coreopsis* spp. Caterpillars (larval stages of insects) mainly occurred on cruciferous plants (e.g., *Aubrieta* spp., *Aurinia* spp., candytuft, *Alyssum* spp.) and stock, but were also reported on poinsettia. Root maggots were mainly a problem on cruciferous plants such as *Astilbe* spp., *Aubrieta* spp., *Aurinia* spp., candytuft, *Alyssum* spp., and stock.

Controls

Cultural

Growers surveyed practiced weed control under benches to control of many insects, especially aphids, thrips, and whiteflies. Of the greenhouses surveyed, 12% had a double entryway door to reduce the spread of insects and diseases through the door, while 25% had screen-covered vent and fan openings. One grower controlled mealy bugs by taking plants outside and using a moderately high-pressure water stream to physically knock the insects off the plant. Plants were moved back into the greenhouse the next day. This practice would not be practical for a larger operation. All growers utilized yellow or blue sticky cards to monitor for the appearance of fungus gnats, thrips, whiteflies, and other insects. If checked frequently and regularly, sticky cards allow for early detection of an insect population and subsequent implementation of cultural, biological, and/or chemical controls when the population is at or below threshold levels.

TABLE 3

Selection of disinfectants, fungicides, and insecticides used by eight greenhouses in Washington as reported in summer 2000 interviews.

FUNGICIDES	INSECTICIDES
Aliette 80WDG (fosetyl-al)	Adept 25 (diflubenzuron)
Banol (propamocarb)	Astro (permethrin)
Banrot (etridiazole + thiophanate methyl)	Avid (avermectin)
Botran 75 (dichloran)	Azatin 3 (azadirachtin)
Captan 50 (captan)	BotaniGard ES (*B. bassiana*)
Champ II (copper hydroxide)	Cinnamite 30 (cinnamaldehyde)
Chipco 26019 50WP (iprodione)	Citation 75 (cyromazine)
Cinnamite 30 (cinnamaldehyde)	Conserve (Spinosyn A+D)
Cleary's 3336F (thiophanate methyl)	DuraGard 20 (chloropyrifos)
Compass 50 (trifloxystrobin)	Dursban 50W (chloropyrifos)
ConSyst WDG (chlorothalonil + thiophanate methyl)	Endeavor (pymetrozine)
Curalan EG 50 (vinclozolin)	Enstar II 65 (s-kinoprene)
Daconil ZN (chlorothalonil)	Floramite 50 (bifenazate)
Decree 50WDG (fenhexamid)	Gnatrol (*B. thuringiensis* var. *israelensis)*
Dithane T/O 58 (EBDC)	Kelthane T/O (dicofol)
Exotherm (chlorothalonil)	Knoxout 23 (diazinon)
Fore and Fore FloXL (EBDC)	Marathon 60 (imidacloprid)
Heritage 50WG (azoxystrobin)	Mavrik (fluvalinate)
Kocide 2000 (copper hydroxide)	Mesurol 75WP (methiocarb)
Medallion 50 (fludioxonil)	M-Pede (insecticidal soap)
Ornalin FL 41 (vinclozolin)	MVP II (*B. thuringiensis* endotoxin)
Penncozeb (EBDC)	Orthene 75 (acephate)
Plantvax 75 (oxycarboxin)	Pinpoint 15 granular (acephate)
Pipron 85 (piperalin)	Precision WP (fenoxycarb)
Phyton 27 (CuSO4 pentahydrate)	Pyrigro (pyriproxyfen)
Protect T/O (EBDC)	Py-Rin (pyrethrins)
Strike 25 WP (triadimefon)	Resmithrin EC (resmethrin)
Subdue MAXX (mefenoxam)	Sunspray Oil 11E/6E (paraffinic)
Systhane WSP 40 (myclobutanil)	Sanmite (pyridaben)
Terraclor 75 WP (quintozene)	Talstar GH (bifenthrin)
Terraguard 50 (triflumizole)	Tame 31 (fenpropathrin)
Truban 30WP (etridiazol)	Thiodan 50WP (endosulfan)
Zyban (EBDC- Zn + thiophanate methyl)	Topcide 10 (lambda-cyhalothrin)
	Turcam 76 (bendiocarb)
DISINFECTANTS	
ZeroTol (hydrogen dioxide)	Green-Shield (quaternary ammonium)

Biological

A number of products are available for biological control (Table 4). Most businesses have tried biological controls for insects, and use is becoming common (50% of businesses surveyed incorporated use of biological control products as a major part of their insect pest management program). At this point, the industry has limited experience with use patterns. The general strategy is to schedule a tank mix of several insecticides early in the cropping season, then one to two weeks later start scheduled releases (e.g., monthly) of multiple organisms through the duration of that cropping cycle. Control is not comparable to chemical counterparts.

TABLE 4

Commercial biological organisms used to control insect pests of bedding plants in Washington.

Scientific Name	Release Rate (per 100 sq ft)	Mode of Attrition*	Target Organisms
Aphidius matricariae	15-70	parasitism	aphids
Aphidoletes aphidimyza	105	predation	aphids
Encarsia formosa	250	parasitism	greenhouse whitefly
Hippodamia convergens	160	predation	aphids, fungus gnats, thrips, whiteflies
Hypoaspis miles (= *Stratiolaelaps*)	100	predation	fungus gnats, flower thrips
Neoseiulus cucumeris (= *Amblyseius*)	250-600	predation	thrips, cyclamen mite, broad mites

*** Parasites typically lay eggs on or in the pest and the juvenile stage of the parasite will use the pests as a food source. Predators typically feed directly on the pests, although the mode of feeding will vary from chewing to drawing out bodily fluids.**

Chemical

Tables 2 and 3 (pages 4 and 5, respectively) show the insecticides used by Washington bedding plant growers. Proper selection of pesticides is a necessary part of the current pesticide resistance management strategy.

To combat resistance development, three to six products may be used in rotation, either singly or in tank mixes, against one specific pest. Strategies included tank-mixing and rotational selection of different classes of insecticides. Applications are selective, but insecticides are used throughout the year with no particularly high or low use periods.

Tank mixes were used to control insect pests more than to control pathogens. Along those same lines, more biological controls are used to control insects, so some of the tank mixes are to reduce populations of several insects and are then followed after a two-week interval by the release of biological control organisms (Table 4). For example, tank mixes used to control aphids included selections such as Talstar plus Azatin 3, Talstar plus M-Pede, Orthene plus Tame, and Orthene plus Avid. Some of these mixes also provided control of other insects such as spider mites. Endeavor plus Conserve was used to control scale insects.

Many of the growers (88%) reported using repellents such as garlic oil and hot pepper wax. These work as preventives with limited knockdown capability. Ultra-fine oils were used to control scale and aphids.

Diseases

Disease in bedding plants can cause loss in revenue in several ways. When plants have visible damage from disease (blemishes, poor size or bloom characteristics, dead tissue), they fail to meet market criteria and do not generate revenue. (No attempt was made in this profile to quantify the value of plants discarded or devalued due to disease.)

Excessive disease control costs can also negatively impact revenue. The level and frequency of disease control is typically based on the severity and/or frequency of pest damage and the value of the crop. The price of ornamental plants is directed related to physical appearance. Pest control is implemented to prevent visual damage and death, and it is also necessary to achieve marketable growth attributes in a specified time period. Slow growth or a need to promote new growth to compensate for damaged tissue can result in plants being unavailable during high demand periods. Demand is associated with seasonal holidays and

favorable climate during spring and fall periods. Price and volume of sales are directly related to these windows of opportunity and the continued success of ornamental businesses that deal with bedding and flowering plants. Delaying production by one or more weeks can significantly reduce returns.

The most common diseases reported in Washington State bedding plants were **gray mold** (*Botrytis cinerea*) and **root rot** (*Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp.), which occur on many of the bedding and flowering plant species produced in Washington. All other disease problems occur on a narrower selection of plant species. Black root rot (*Thielaviopsis basicola*) commonly occurs on *Fuchsia* spp., *Petunia* spp., and *Viola* spp. (pansy), but can also be found on *Begonia* spp., *Gerbera* spp. (African daisy), *Pelargonium* x *hortorum* (florist's geranium), and other annuals. Powdery mildew (*Erysiphe* spp., *Microsphaera* spp., *Spaerotheca* spp.) is a common foliar problem on many hosts, such as varieties of *Anemone* spp., *Aquilegia* spp. (columbine), *Begonia* spp., *Gerbera* spp. (African daisy), *Phlox paniculata*, and *Verbena* spp. Downy mildew (*Peronospora* spp.) is a foliar disease that has become increasingly problematic over the last five years. Each species of downy mildew has a narrow host range, but the various species have become a problem on a large number of bedding and flowering plants, such as *Antirrhinum* spp. (snapdragon), *Buddleia* spp., *Delphinium* spp., *Digitalis* spp. (foxglove), *Galium* spp. (bedstraw), *Iberis* spp. (candy tuft), *Lamium* spp., *Limonium* spp. (statice), *Phlox* spp., *Salvia* spp. (sage), *Veronica* spp. (speedwell), and *Viola* spp. (pansy).

Many **fungal diseases** occur less frequently or on a narrower range of plant species. Alternaria and Cercospora leaf spots occur on several hosts; the most commonly reported was *Viola* spp. (pansy). Myrothecium, Ramularia, and Septoria leaf spots were reported to occur infrequently on hosts such as *Salvia* spp. and *Viola* spp. (pansy). Several rusts were reported, such as *Puccinia salviicola* on salvia, *Puccinia pelargonii-zonalis* on geranium, and *Pucciniastrum epilobii* on fuchsia. White rust (*Albugo* spp.) was reported by 25% of growers as a problem on *Iberis* spp. (candy tuft) and by another 25% on *Senecio* spp. (dusty miller). *Verticillium dahliae* can occur on bedding plants and was reported on begonia and geranium. Verticillium wilt was reported as an infrequent disease by 38% of growers. Vascular wilt caused by *Fusarium oxysporum* was not reported, but likely occurred and was not properly diagnosed. Fusarium stem rot, possibly caused by *F. moniliforme* or *F. solani*, was reported as a specific problem that was controlled. It is assumed that this list of diseases is incomplete.

Bacterial diseases are less common but not infrequent. *Xanthomonas campestris* is a problem on *Geranium* spp. and *Pelargonium* spp. (geranium). *Pseudomonas* spp. have been identified as causing leaf spot diseases on several hosts, such as *Geranium* spp. (geranium), *Impatiens* spp., and *Pelargonium* spp. (florist's geranium). Erwinia soft rot was reported as an infrequent cause of stem rot of cuttings.

Viral diseases occur on bedding and flowering plants, but few specific occurrences were reported. Impatiens necrotic spot virus (INSV) was reported, but only on a few plant species (begonia, impatiens, and verbena). Other viruses found on *Verbena* spp., *Nenesia* spp., and *Scabiosa* spp. were cucumber mosaic virus (CMV), tomato mosaic virus (TMV), and flower break potyvirus.

Gray mold was predominately a problem during winter production periods, but requires some control effort even during the summer. Downy mildew is a severe problem during the winter on specific crops. Pythium root rot is thought to be the most common root rot problem of bedding plants in Washington and this is probably true during winter and spring production periods. Rhizoctonia root rots occurs less frequently but is more likely found from spring, summer, and fall periods. Limited Rhizoctonia foliar blight was present on cuttings being rooted in mist houses during the spring and was also seen on salvia. Powdery mildew requires control effort during the spring and fall. Black root rot was reported to cause more severe damage on susceptible crops (fuchsia) produced during the summer, yet was a problem on a few crops grown in late winter and early spring (petunia).

Controls

Cultural

Cultural practices are extremely important in the control of disease problems. These practices can be grouped into several broad categories: sanitation, modifying environmental conditions, optimizing plant care requirements, segregation of susceptible varieties or valuable plants from tolerant plants that harbor pathogens, and scouting.

All growers, without exception, remove infected plants from their greenhouses and control weeds, which can became a reservoir for disease (and insect) pests.

High relative humidity (RH) and free moisture on upper plant surfaces is conducive to development of many diseases. RH is difficult to control, especially at low temperatures. To maximize returns, plants are bunched. Forty-three percent of growers emphasized selective use of proper plant spacing to decrease RH; spacing also allows better penetration of the chemical controls when applied. Spacing tended to be more commonly used on higher value crops as the plant reached finish size. All growers selectively opened vents to increase air movement; 29% used fans. Fifty-seven percent of growers heated their greenhouses late in the evening then proceeded to vent the air to decrease condensation. Heating is a costly practice that is not used for all crops. Thirty-eight percent of the businesses selectively used energy curtains in the evening to partition a smaller space to be heated and reduce heat loss.

Mat irrigation systems on bench tops were used by 42% of growers; these help avoid wetting plant foliage. A flood-floor system was employed by 14% of growers, greatly reducing leaf spot diseases and gray mold, but not resulting in increased root rot.

Virus indexing of propagation stock is the main cultural practice used to control virus diseases. Virus indexing is done with a number of bedding and flowering plant species, most notably with geraniums. To minimize past losses from Impatiens Necrotic Spot Virus (INSV) some businesses reduced or eliminated highly susceptible plant species, such gloxinia and New Guinea Impatiens, from their plant selection.

Biological

Biological controls were used to a greater degree in insect control versus pathogen control. The only biological control products reported were Bio-Trek *(Trichoderma harzianum)* and RootShield *(Trichoderma harzianum)*. One grower who used Bio-Trek had root rot problems at times when Bio-Trek was used alone; therefore newly seeded or stuck plug trays were drenched with Subdue MAXX then drenched with Bio-Trek two weeks later.

Chemical

Fungicides are used in conjunction with cultural and biological controls. University experimental trials and actual disease occurrences in commercial plant production operations demonstrate the importance of integrated pest management and the necessity of a variety of control methodologies, including chemical control. While six diseases (gray mold, downy mildew, Pythium root rot, powdery mildew, and black root rot) are the most persistent problems, a wide range of diseases can be problematic among the more than 150 bedding plant species grown in Washington. In spite of the damp Northwest climate, diligent implementation of good cultural practices has diminished the potential severity of fungal leaf spot diseases, such as rusts, and of certain viruses.

A large selection of fungicides (see Table 3, page 5) is used as a necessary part of current pesticide resistance management strategy. To combat resistance development, three to six products may be used against one specific pathogen; these are typically used in rotation, either singly or in tank mixes.

Most fungicide applications are spot treatments to areas less than 200 sq. ft. in small operations and between 200 to 4000 sq. ft. in large operations, which equates to a coverage of < 1 to 6% of the total production area. Only rarely were fungicides applied to large square footage. Because different products are rotated and spot treatments are predominant, the volume of pesticide used is lower than might be presumed by the long list of products. (No attempt was made to calculate volumes of each product used.)

While the pattern of product selection differed between businesses, applications were made throughout the year with peak periods of use in February to April and from October to December. The most commonly used products were Aliette 80WDG, Chipco 26019 50WP, Cleary's 3336F, Daconil, Decree 50WDG, Phyton 27, and Subdue MAXX.

Fosetyl-al (Aliette 80WDG) is rotated with mefenoxam (Subdue MAXX) during the summer and early fall for control of Pythium root rot. Subdue MAXX is at risk of pathogens developing resistance, while it is less likely with Aliette. During the winter, Aliette 80WDG may be used to control downy mildew. Subdue MAXX would still be used to control Pythium root rot during that time on crops that aren't susceptible to downy mildew. Other chemicals used to control Pythium root rot included etridiazol (Truban 30WP), etridiazol + thiophanate methyl (Banrot), and propamocarb (Banol).

Interestingly, 38% of businesses reporting (all of them moderate-sized) had few root rot problems and correspondingly made no more than two applications per year of Aliette 80WDG or Subdue MAXX to crops in the pot size intended for shipping and direct sales. Another 38% routinely drenched Subdue MAXX in plug trays after seeding or sticking cuttings. Treating plants in small plugs reduces the total volume chemical required versus waiting until plants are potted in larger pot sizes. Some also used a biological control product (Bio-Trek). A few of the smaller businesses kept potting media on the dry side, a task more easily done when one to two people do all the watering by hand. See additional information on Pythium root rot control in the Cultural and Biological Control sections.

Gray mold was controlled with azoxystrobin (Heritage 50WG), captan (Captan 50WP), chlorothalonil (ConSyst WDG, Daconil, Exotherm), copper sulphate pentahydrate (Phyton 27), ethylene bisdithiocarbamate (Dithane T/O, Fore F, Fore FloXL, Penncozeb DF, Protect T/O), fenhexamid (Decree 50WDG), fludioxonil (Medallion 50), iprodione (Chipco 26019 50WP), dichloran (Botran 75), thiophanate methyl (Cleary's 3336F), trifloxystrobin (Compass 50), and vinclozolin (Ornalin FL, Curalan EG 50).

Rhizoctonia root rot was controlled with azoxystrobin (Heritage 50WG), etridiazol + thiophanate methyl (Banrot), fludioxonil (Medallion 50), iprodione (Chipco 26019 50WP, Ornalin FL), quintozene (Terraclor 75WP), thiophanate methyl (Cleary's 3336F), and trifloxystrobin (Compass 50).

Rhizoctonia aerial and stem blight was controlled with the same selection of chemicals with the addition of chlorothalonil (Daconil, ConSyst WDG) and EBDC-Zn + thiophanate methyl (Zyban).

Black root rot was controlled with etridiazol + thiophanate methyl (Banrot), fludioxonil (Medallion 50) and thiophanate methyl (Cleary's 3336F).

Fusarium diseases were controlled with azoxystrobin (Heritage 50WG), chlorothalonil (ConSyst WDG, Daconil, Exotherm), fludioxonil (Medallion 50), and triflumizole (Terraguard 50W).

Powdery mildew was controlled with myclobutanil (Systhane WSP), piperalin (Pipron 85), thiophanate methyl (Cleary's 3336F), triadimefon (Strike 25WP), cinnamaldehyde (Cinnamite), and triflumizole (Terraguard 50W).

Downy mildew was controlled with fosetyl-al (Aliette 80WDG), ethylene bisdithiocarbamate (Dithane T/O 58, Protect T/O) and copper compounds, primarily copper sulfate pentahydrate (Phyton 27).

Rust diseases were controlled with chlorothalonil (Daconil, ConSyst WDG), ethylene bisdithiocarbamate (Dithane T/O, Fore F, Fore FloXL, Penncozeb DF, Protect T/O), EBDC-Zn + thiophanate methyl (Zyban), oxycarboxin (Plantvax 75), and triadimefon (Strike 25WP).

White rust was controlled with copper compounds.

Bacterial diseases were controlled with the copper compounds copper hydroxide (Champ II, Kocide 2000) and copper sulfate pentahydrate (Phyton 27).

Additional Comment on Diseases

Information about the predominant diseases is assumed accurate; usually, they have been clinically diagnosed. The less common diseases are usually diagnosed with the aid of printed resources or with the assistance of other industry professionals. Diagnostic skills vary tremendously; accurate diagnoses require a high level of technical expertise. If someone had Alternaria leaf spot on ornamental pepper, they are likely to attribute a similar leaf spot on another species to the same causative agent. From a practical level, experienced growers usually apply effective controls even if the cause of leaf spot was not properly verified. Still, lack of clinically verified diagnostics becomes a problem when compiling survey information.

Weeds

Weeds (mainly broadleaf dicotyledonous weeds and some monocotyledons or grasses) are a problem in Washington's bedding plant industry. Fewer herbicides are used in greenhouse production than in many other plant production systems. The main purpose of herbicide use in bedding plants is to eliminate sources of insect, fungal, bacterial, and viral pests that damage the crop.

Controls

Cultural

Weeds growing in pots that would compete for plant needs are primarily controlled manually (by hand pulling).

Chemical

All businesses interviewed used herbicides. Total acreage treated was less than an acre even for larger businesses. Smaller businesses often used proportionally more herbicide because of application on soil floors under benches.

The main placement of herbicides is outside of greenhouses, including immediately around structures, along fences, and in decorative flower beds near the greenhouse or nursery entrance. The main purpose is to minimize weed problems inside the greenhouse, as manual weeding is labor intensive. Weed control is also important to minimize spread of disease and insect pest problems.

Selective herbicide applications are made in the greenhouse, usually between crops. Larger operations often completely cover the greenhouses with polyethylene ground cover to reduce weed problems as well as reduce dispersal of pathogens in wet soil. Some small to mid-sized operations (usually older ones) had soil floors directly under their benches. Some newer facilities have polyethylene or concrete floors. Solid walkways between benches are standard.

Scheduled herbicide applications were commonly made in early spring (April) and in the fall (October to December), with selective use during the summer. Twenty-nine percent of the businesses made five applications in one year, but some of those were selectively applied. The remaining 71% made three to four applications per year. Herbicide selection included Roundup DryPak (glyphosphate), Surflan A.S 40 (oryzalin), Scythe (pelargonic acid), and Finale (glufosinate ammonium). Roundup DryPak was most commonly and frequently used, followed by Surflan A.S.

Invertebrates

Slugs were reported as a problem in all greenhouses on many plants. Metaldehyde (Slug-Fest and Mesurol 75WP) was used for control. No other control methods were mentioned.

Additional Needs

The nursery industry has identified liverworts as a serious pest. At present, there are no effective controls. This weed easily infests containerized plants, competes for nutrients, and decreases salability of ornamentals. Liverwort can be a problem in some perennial production. At present, this is an unmet pest control need.

Foliar nematode (*Aphelencoides* spp.) is a problem of increasing importance on a growing number of plants, such as anemone, columbine, and hosta. No chemical treatments are currently labeled for control. Additional research into this area, along with registration of efficacious controls, is a critical unmet pest control need of the Washington State bedding plant industry.

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Use pesticides with care. Apply them only to plants, animals, or sites listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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