Category A: Agricultural Plant Pest Control

Agricultural Plant Pest Control Learning Objectives

THIS CATEGORY IS PART OF THE GENERAL KNOWLEDGE REQUIRED FOR THE GENERAL EXAM FOR PRIVATE CERTIFIED APPLICATORS. NON-PRIVATE CERTIFIED APPLICATORS MAY BE CERTIFIED IN THIS CATEGORY BY TAKING A SEPARATE CATEGORY EXAM.

After studying this section, you should be able to:

- ✓ **Describe some of the most common insect pests of agricultural crops.**
- ✓ **Describe the most common diseases found on common Nevada crops.**
- ✓ **Describe chemigation system design and the purpose of the chemigation hardware.**
- ✓ **List the advantages and disadvantages of chemigation pesticide applications.**
- ✓ **Describe special considerations for greenhouse pesticide applications.**

Category A, Agricultural Plant Pest Control

Category A, Agricultural Plant Pest Control, is the category that covers pesticide applications on crops. This includes fruit and vegetable crops, small grain crops, feed crops and forage crops. It also includes the specialized pest control measures that must be considered in nursery and greenhouse settings, including chemigation. Disinfectants used to sterilize plant containers, working surfaces and equipment in the nursery and greenhouse setting are considered pesticides. Plant growth regulators, used to keep potted flowering plants compact, are also considered pesticides.

Agricultural crop production provides the ideal conditions for weeds to grow ground disturbance, irrigation and even nutrients. The growth of a single

Category A, Agricultural Plant Pest Control includes fruit and vegetable crops, small grain crops, feed crops and forage crops.

type of plant, also known as a monoculture, can provide an ideal setting for diseases and insect pests to develop and thrive. Greenhouse and nursery production can provide a habitat for insect pests and diseases to thrive. Vertebrate pests may also be a concern in cropland, nursery, and greenhouse settings.

Pesticides are often needed to reduce pests to tolerable levels, but they can have serious consequences if applied improperly. Pesticides can harm non-target plants, beneficial insects, wildlife, pets, livestock, and humans. Thoughtful planning and implementation are required to reduce pest pressure, minimize unintended damage, reduce costs, and maximize profit.

The 2021 changes to the certification categories require all PRIVATE Certified Applicators to be tested on both Category A, Agricultural Plant Pest Control and Category B, Agricultural Animal Pest Control as part of the general knowledge exam. For NON-PRIVATE Certified Applicators, Category A, Agricultural Plant Pest Control and Category B, Agricultural Animal Pest Control remain certification categories, with each requiring a separate exam.

Principles of IPM:

- **Identify the pest.**
- **Monitor the pest population.**
- **Establish an action threshold.**
- **Evaluate control options.**
- **Implement control options.**
- **Monitor results.**

For more information on IPM, please refer to the General Knowledge: Integrated Pest Management chapter of this workbook.

Integrated Pest Management (IPM)

The principles of Integrated Pest Management (IPM) can be applied to controlling insect pests, weeds, diseases, and vertebrate pests on agricultural crops, in nurseries and in greenhouses.

- **Pests, their hosts and beneficial organisms must be positively identified.** The pest problem and associated plant species must be correctly identified. If you can't identify the pest, collect samples and submit them to the University of Nevada, Reno Extension or the Nevada Department of Agriculture for identification. Once the pest has been identified, determine its life cycle, growth cycle and reproductive habits. Pest managers should also be able to identify all life stages of beneficial organisms, such as the ladybird beetle, an insect predator.
- **Establish monitoring guidelines for each pest species.** Routine monitoring of both pests and natural enemies (beneficial species) is an essential part of IPM. Methods of monitoring include visual inspection, pheromone and sticky traps, and sweep nets. Document and track both pest and beneficial organism population numbers. The ratio of natural enemies (usually insects) to pests should be considered before a pesticide is applied.
- **Establish an action threshold for the pest**. A fundamental concept of IPM is that a certain number of individual pests can and should be tolerated. Will the pest cause unacceptable damage to the value the crop or other agricultural product? **What will happen if no action is**

taken? The action threshold in agricultural production is generally based on economics. The **economic threshold** is defined as the pest population level that produces damage equal to the cost of preventing or reducing damage by controlling the pest. The threshold is the pest density, or population level, at which a pesticide or other control method should be implemented.

- **Evaluate and implement control tactics.** Select tactics that will be most effective, most economical and have least impact on non-target species and the environment. Select controls that will harm beneficial organisms as little as possible while suppressing the pest. If a pesticide is one of the selected management tools, beneficial enemies (usually insects) will likely also be killed.
- **Monitor, evaluate and document the results.** This allows you to make adjustments to improve the effectiveness of future pest control strategies.

For further information on Integrated Pest Management, consult the General Knowledge: IPM chapter in this manual.

Worker Protection Standard (WPS)

The Worker Protection Standard (WPS) is a regulation issued by the U.S. Environmental Protection Agency. It covers pesticides that are used in the production of agricultural plants on farms, forests, nurseries and greenhouses. The WPS requires you to take steps to reduce the risk of pesticide-related illness and injury if you (1) use pesticides or (2) employ workers or pesticide handlers who are exposed to pesticides. If you are an agricultural pesticide user and/or an employer of agricultural workers or pesticide handlers, the WPS requires you to provide the following to your employees and, in some cases, to yourself and to others:

Information about exposure to pesticides: To ensure that employees will be informed about exposure to pesticides, the WPS requires:

- Pesticide safety training for workers and pesticide handlers.
- A pesticide safety poster be displayed for workers and pesticide handlers.
- Access to pesticide labeling information for pesticide handlers and early-entry workers.
- Access to centrally located information detailing pesticide applications that have occurred on the establishment.

Protection against exposures to pesticides: To ensure that employees will be protected from exposures to pesticides, the WPS requires employers to:

The Worker Protection Standard (WPS) applies to workers on farms, forests, nurseries and greenhouses.

In 2015 the EPA revised the WPS. A synopsis of the 2015 changes can be found in the Pesticides and the Law chapter of this workbook.

For further information on the WPS, consult the U.S. EPA web publication "How to Comply With the 2015 Revised Worker Protection Standard for Agricultural Pesticides: What Owners and Employers Need To Know" at http://pesticideresources.org/wps/htc/htcmanual.pdf

Effective control measures require correct identification and a thorough understanding of the pest's life cycle and biology.

- Prohibit handlers from applying a pesticide in a way that will expose workers or other persons to pesticides.
- Exclude workers from areas being treated with pesticides.
- Exclude workers from areas that remain under a restricted-entry interval (REI), with narrow exceptions.
- Protect early-entry workers who are doing permitted tasks in treated areas during an REI, including providing special instructions related to the correct use of personal protective equipment (PPE).
- Notify workers about treated areas so they can avoid inadvertent exposures.
- Protect handlers during handling tasks, including monitoring while handling highly toxic pesticides and providing special instructions related to the correct use of PPE.

Mitigation of pesticide exposures: To mitigate pesticide exposures that employees receive, the WPS requires that:

- Decontamination supplies are available to all workers. Employers must provide pesticide handlers and workers with an ample supply of water, soap and towels for routine washing, and emergency decontamination.
- Emergency assistance information is available to all workers. Employers must provide transportation to a medical care facility if an agricultural worker or handler may have been poisoned or injured by a pesticide, and they must provide information about the pesticide(s) to which the person may have been exposed.

Insect Pests

Basic insect identification information can be found in the General Knowledge: General Pest Problems section of this manual.

In the natural environment, where a finite number of plant species occur together, insects are normally kept in check by limited food supply, environmental conditions and natural predators. In the monocultures formed by agricultural crop production and in greenhouses and nurseries, however, some insects may become pests because large numbers of susceptible plants are grown together in close quarters. Abiotic stresses or other injuries make plants more susceptible to insect attack.

Insects and related arthropods are responsible for many kinds of plant disorders. Their damage is often difficult to distinguish from that caused by disease or abiotic problems. Insect injury is confirmed by finding the causal insect. However, the insects you find on an injured plant may have nothing to do with the damage. Sometimes damage is observed only after the

responsible insect has completed the damaging part of its lifecycle. It is important to become familiar with insect pests commonly found on plants in the nursery and greenhouse and on field crops. Effective control measures require correct identification and a thorough understanding of the pest's life cycle and biology.

Insects can damage plants in the following ways. They may:

- Feed on leaves.
- Feed on and move into fruit, seeds, and nuts.
- Feed on and tunnel into roots.
- Tunnel or bore into stems, stalks, branches, and trunks.
- Suck sap or juices from leaves, stems, roots, fruits, and flowers.
- Act as vectors, transmitting disease pathogens as they feed.

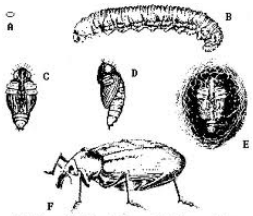
Insect outbreaks often result from one or more of the following factors:

- Large scale planting of a single crop (the basis of modern agriculture).
- Introduction of an insect pest into an area with no natural enemies.
- Favorable weather conditions that aid in rapid development and reproduction. These same weather conditions may be unfavorable to natural enemies.
- Use of insecticides that kill natural enemies or reduce competing species of pests.
- Cultural practices that encourage the pest infestation.
- Other factors that destroy the natural food chain that normally helps keep the pest insect population in check.

Specific Insect Pests in Agricultural Plants

Alfalfa weevil: This is the most serious insect pest of alfalfa in Nevada. Adult alfalfa weevils overwinter in surrounding vegetation and field trash. In early spring, adult females deposit eggs in stems of alfalfa, the eggs hatch and larvae make their way to the growing tips and upper leaves, where they feed. Feeding damage results in a skeletonized appearance on the leaves. Severe damage can give the field a grayish to whitish cast, as if it had been frosted. Mature larvae make their way to the base of the plant and pupate. On rare occasions, newly emerged adults may cause damage to the second crop. Alfalfa weevil damage is most commonly seen before the first cutting.

Healthy plants are better able to tolerate insect feeding. Resistant cultivars are available. Early cutting can be an alternate to chemical applications, if economically feasible. Cutting will reduce numbers and interrupt the insect's life cycle.



Alfalfa weevil. A, Egg. B, Larva. C-D, Pupae. E, Pupa in cocoon. F, Adult.

Alfalfa weevil
ipm.ncsu.edu

Proper timing is extremely important when applying insecticides to control alfalfa weevils.

Mites are not insects, but arachnids; they have eight legs.

Mites often appear under dry conditions prior to the first irrigation.

Almost every plant has its own type or types of aphid pests.

The best time for chemical control is in the larval stage. Compounds previously used for controlling adults have been canceled. Therefore, treat only for larvae. Proper timing is extremely important when applying insecticides to control alfalfa weevils.

Mites: Mites are not insects, but arachnids. They have two body parts and eight legs. Mites often appear under dry conditions prior to the first irrigation. Often the first irrigation will reduce their populations by knocking them off the plants and interrupting their life cycle. Mites cause damage by sucking plant juices. Damage first appears as stippling (small yellow areas) on leaves. Severe damage causes leaves to dry and then drop from the plant. The mites are found on the undersides of the leaves and the infestation usually starts on the lower, older leaves and moves upwards.

Minimizing plant stress through improved cultural practices, such as proper irrigation and fertilization, can aid plants in withstanding an infestation. Cleaning up field debris is important to reduce overwintering populations and reducing pressure on next season's crop. Bush beans have been shown to be an excellent early indicator of spider mite presence in tomato and pepper crops, showing damage weeks before the crop. A number of predatory mite species have been developed into effective biocontrol's for control of mites on greenhouse crops and in orchards. Some of these predatory mites, such *Amblyseius fallacis*, feed on pollen when pests are not present and are effective when released early in the season before pest pressure is detected. Other species, such as *Phytoseiulus persimilis*, are highly specific to the target pest and can provide good control when released after pests have been detected. It is essential to select biocontrol species based on environmental conditions, as establishment depends on suitable temperature, humidity, and day length. Additionally, proper identification of pest species is necessary; some biocontrol species are generalist predators, while others are highly specific to the target pest. Biocontrol suppliers and crop advisors can aid in selection of biocontrol's appropriate for the environmental conditions and target pest. Mites can be controlled with acaricides (pesticides that kill mites).

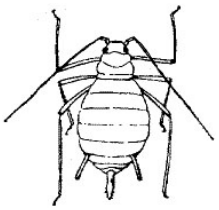
Aphids: Almost every plant has its own type or types of aphid pests. Aphids are soft-bodied insects with piercing mouthparts that are used to suck out plant fluids. Some species inject toxins into plants, resulting in distortion of the leaves. Some species are also vectors of plant diseases. Heavy infestations can reduce plant vigor, causing stunting in plants and causing leaves to wilt, curl, yellow or become mottled. It is extremely important to identify the specific aphid species that is attacking the crop, since thresholds and the effectiveness of chemicals may vary from species to species.

The typical aphid overwinters as either a sexually produced egg or as an adult female. This may occur on a summer host or on an alternate winter host. In the spring, eggs hatch, producing winged adults, or the overwintering adult females move to the summer host. The females mature and begin producing offspring without being mated. This is referred to as asexual reproduction. This may be repeated (adult to adult) in the summertime as often as once a week.

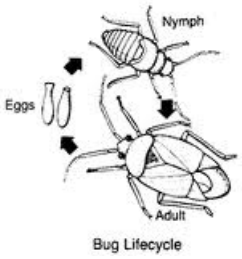
Cultural practices that promote vigorous plant growth can help plants tolerate aphid feeding. Resistant cultivars are available. Early harvesting may help to reduce numbers. The effect of naturally occurring pest predators should not be discounted and should be thoughtfully considered when selecting pesticides for controlling aphids. Parasitoid wasps, minute pirate bugs, lacewings, syrphid flies and ladybird beetles can be attracted in large numbers to fields and high tunnels by providing pollen-producing plants interplanted in the crop or along field boarders. Sweet alyssum, buckwheat and marigolds are commonly used in combination to provide season long pollen and habitat for these species. IPM programs for various greenhouse crops have been developed based on parasitoid wasps of the genus *Aphidius* and the predatory midge *Aphidoletes aphidimyza*. Biological control using naturally occurring pest predators can keep aphid numbers below action thresholds. Chemical controls should be applied thoughtfully to minimize injury to these beneficial insects.

Lygus bugs: These are primarily pests on alfalfa seed but can cause some damage on hay. Lygus bugs damage plants by puncturing plant tissues with their piercing mouthparts and feed by sucking sap. In addition to the physical injury they cause by feeding, females also damage plants when they lay eggs directly into plant tissues using their piercing ovipositors. This is usually a problem on other crops grown for seed. Lygus bugs preferentially target growing points (buds, flowers, seed pods) and can significantly reduce plant maturation, seed set and seed yield. Control is difficult, and the best success is achieved with pesticide applications aimed at the smaller nymphs. Monitor for lygus bugs prior to first bloom so treatment decisions can be made prior to pollinator release. Apply chemical controls in the late evening or early morning when pollinators are not active.

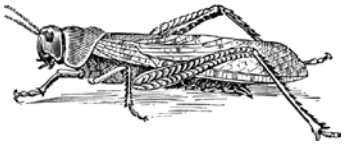
Cutworms: Cutworms are an occasional problem in all agricultural crops. Early detection is very important. Symptoms often show up as “late spots” in alfalfa fields. In row crops, young seedlings will be severed at ground level. If populations are high enough (about 1/sq. ft.), controls are warranted. Baits can be applied, but often bait acceptance is a major problem. It is important to know which cutworm or armyworm you are dealing with, since many are



Aphid
extension.missouri.edu



Lygus bug
www3.telus.net



Grasshopper

It is important to report Mormon cricket infestations to the Nevada Department of Agriculture (NDA) using the form found at this link: https://agri.nv.gov/uploadedFiles/agrinvgov/Content/Resources/Forms/Plant/Entomology/mc_gh_form_2013_4.pdf.

nocturnal and, for these species, you must spray in the late afternoon or evening to get adequate control. Tillage and flood irrigation can reduce cutworm populations.

Grasshoppers: Large grasshopper populations generally develop on non-cultivated land or on land that has been left fallow or abandoned. These grasshopper populations or "bands" then move to agricultural lands and feed on crops. Controls must be aimed at the entire band of grasshoppers. Treating only a portion of the band will often result in rapid re-infestation of the treated area. Treatment must also occur before grasshoppers begin laying eggs.

If properly treated, grasshoppers can be controlled in an area for up to five years. Control measures include several chemical controls. Remember to make sure the crop or site is specified on the product's label. *Nosema locustae* is a disease of grasshoppers**.** This biological control can be used effectively against grasshoppers if the proper conditions exist. Success is most dependent on the grasshopper species present, the life stage of the grasshopper, and the habitat conditions.

Mormon crickets: Mormon crickets are not true crickets. They are shield-backed, short-winged katydids. They resemble fat grasshoppers and cannot fly. Similar to grasshoppers, they have cyclic population increases. Mormon crickets form bands that feed on almost any plant material, but they prefer succulent forbs. They damage rangeland forbs, grasses and shrubs. They can also damage small grains, alfalfa, and most other crops. Their presence can also cause losses to forage crops they don't eat; hay quality significantly drops if the hay is full of Mormon crickets and their droppings. It is important to report Mormon cricket infestations to the Nevada Department of Agriculture (NDA) using the form found at this link: https://agri.nv.gov/uploadedFiles/agrinvgov/Content/Resources/Forms/Plant/Entomology/mc_gh_form_2013_4.pdf. Reporting to the NDA helps in controlling the current infestation and in predicting future infestations.

Control of Mormon crickets is an ongoing battle in Nevada. Physical or mechanical control by creating a barrier is usually impossible over large land areas. Biological controls include wild birds and poultry. A black wasp (*Palmodes laeviventris*) has been reported to be a Mormon cricket predator. A parasite (*Varimorphan* sp.) occurs naturally in populations of Mormon crickets and can be devastating in the early nymph stages. Unfortunately, this parasite is not commercially available. Several different chemical controls, with different modes of action, are available. Pesticide baits are also available. Since Mormon crickets cannibalize their dead, the bait that kills one Mormon cricket may kill a second or third with subsequent feeding

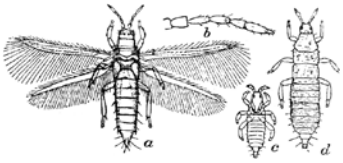
within the band. If you are using chickens as a biological control, you may not want to use these baits or many of the other chemical controls. Other chemical controls include growth regulators. The choice of growth regulator is based on several factors, including the age of the cricket population, forage conditions, labeled sites for use with each growth regulator, weather and environmental impacts. Check with your local pesticide dealer for the most up-to-date chemical control products available for your site and situation.

Thrips: These are important pests of onions and garlic. On these crops, the economic threshold is about 10 insects per leaf. Thrips are vectors for a number of economically important viruses, such as Tomato Spotted Necrotic Wilt Virus (TSNW). Thrips on other crops can cause cupped or silvered leaves, deformed flowers and problems in pollination, resulting from their rasping style of feeding.

Thrips are very difficult to control. Blue sticky cards can be used to monitor for thrips arrival and population numbers in established infestations. Identification of thrips species and survey of damage are important prior to control measures. Beneficial predatory thrips commonly occur in agricultural crops and don't cause damage to plants; they may contribute to suppression of pests. Consider crop rotation and sanitation near crops, such as removing alternate host plants and planting trap crops. Biocontrol programs have been developed for greenhouse cucumbers using a combination of the predatory mites *Amblyseius cucumeris* and *Stratiolaelaps scimitus*. Chemical controls may also be used for control.

There are several varieties of **stink bugs**. They feed on a variety of plants, resulting in seedling death, and stunting of plants. As they feed on plants, they leave a brown liquid called frass, a mixture of excrement and honeydew, which dries to brown spots. They overwinter on plants and in plant debris, so sanitation can help reduce populations.

One species of stink bug, **the brown marmorated stink bug (BMSB)**, is causing problems in the eastern United States. It has been found in Nevada and adjacent states. It is 1/2 to 3/4 inch long, marbled brown and shield shaped. Its antennae have white bands, and the edges of its abdomen have alternating light and dark markings. Like most stink bugs, they stink when crushed. BMSB attacks over 170 plant species, including fruit trees. Their piercing/sucking mouth parts cause a variety of damage symptoms, depending on the plant or crop. Additionally, they emit aggregation hormones in the fall and overwinter in homes in attics, crawl spaces, etc. All stink bug controls, including BMSB, include exclusion from homes and debris clean up to prevent overwintering sites. Light and pheromone traps may be



Thrips

BMSB, Dr. Janos Bodor, Calphotos.

BMSB eggs and nymphs, Dr. Janos Bodor, Calphotos.

Emerald Ash Borer with paperclip for scale. Kenneth R. Law, USDA APHIS PPQ, Bugwood.org.

White satin moth. Perry Hampson, Bugwood.org.

effective. Biological controls include birds that eat adults and beneficial insects, such as lady bugs and lacewings, that consume the eggs. Stink bugs are difficult to control using pesticides. For more information on BMSB, go to www.stopbmsb.org.

Emerald ash borer (EAB) is an exotic beetle that attacks ash trees. Adult beetles are metallic green and about ½ inch long. The larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. Adults leave a D-shaped exit hole in the bark when they emerge in spring. Adults remain active until the end of summer.

Emerald ash borer is thought to have arrived in the United States on solid wood packing material carried in cargo ships or airplanes originating in its native Asia. As of October 2018, it is now found in 35 states, and the Canadian provinces of Ontario, Quebec, New Brunswick, Nova Scotia and Manitoba. Part of the spread of the EAB is through moving firewood.

Prevention measures include a ban on moving firewood from areas with an infestation. Monitor for this pest. New infestations are difficult to detect, as damage to the tree may not be apparent for up to three years. Symptoms of an infestation can include branch dieback in the upper crown, excessive suckers or water sprouts forming on the tree trunk, and vertical bark splits. Woodpeckers like EAB larva, so heavy woodpecker damage on ash trees may be a sign of EAB infestation. There are several different types of chemical controls that may be effective, including systemic insecticides applied as a soil drench and soil or truck injections. New formulations are being tested for effectiveness against EAB; consult with your pesticide dealer for the latest formulations. Read, understand and follow label directions. For more information and to track the spread of EAB, go to the EAB Information Network at http://www.emeraldashborer.info/.

A caterpillar pest causing damage in forest and landscape trees in Nevada is the **white satin moth**. The caterpillar of white satin moth causes damage by feeding on poplar, cottonwood, aspen and willow, and sometimes on oak and crabapple trees. The caterpillar will skeletonize leaves by feeding on the leaf tissue between the veins. Extensive infestations can cause defoliation and branch dieback. Severe infestations can cause tree death.

Adult moths are about 1 inch in length and may have a wingspan of up to 2 inches. They have a silvery-white body and satin-like wings. Caterpillars vary in color from pale to medium grayish brown to black. Full sized caterpillars are 1.75 inches long. They have a very distinctive pattern of markings on their backs. A row of yellowish or milky white circular shapes runs down the length of its back, with rows of reddish-brown circles in pairs on either side of the yellowish or milky white circular shapes. Additionally, tufts of reddish-brown hairs stick straight out of its sides and back.

The life cycle of the white satin moth is unusual. It overwinters as a caterpillar, emerging to feed in the spring. In early summer, the caterpillars spin cocoons, and the moths emerge shortly afterwards. The moths lay egg masses until late summer, and young caterpillars feed in late summer to early fall. For this reason, the full-sized caterpillars actually show up in the early spring while the newly hatched caterpillars show up during late summer/early fall.

Scout regularly for these pests. Keep landscape trees healthy by managing water and pruning properly. Biological controls include birds, parasitic wasps, lacewings, predatory mites, and some beetle species. A microbial insecticide, *Bacillus thuringiensis kurstaki* (Btk), can be effective on the caterpillar stage of the white satin moth. This material must be ingested by the caterpillars as they feed on the leaves. Repeated application may be required as the application may wash off. Chemical controls include several foliar-applied insecticides. Some of these insecticides are toxic to beneficial insects and pollinators, so applications should not be made when the trees are blooming. These are foliar applications, not systemic insecticides, so large trees may be difficult to completely treat. Systemic insecticides are not effective. New insecticide formulations are being developed all the time; consult with your pesticide dealer for the latest formulations that may be effective for white satin moth control. For more information go to https://forestry.nv.gov/uploads/missions/20210302_AMT_2019_White_Satin_Moth_Fact_Sheet.pdf.

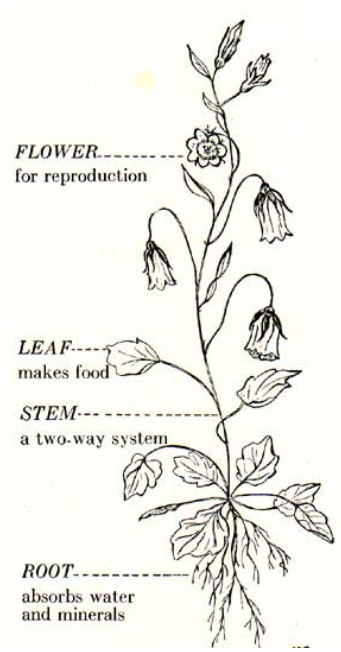
Gypsy moth (aka spongy moth): There are two varieties: European gypsy moth and Asian gypsy moth. Both have a voracious appetite and will attack more than 300 species of trees and shrubs. Both overwinter as eggs, which are laid in sheltered areas, such as underneath the bark of trees, eaves of homes and other structures or other outdoor objects. Eggs hatch in the spring. Caterpillars are striking, with five pairs of blue dots followed by six pairs of red dots along their backs. The body of the caterpillar is dark colored with light brown hairs. The older caterpillars are 1.5 to 2 inches long. In early summer, the caterpillars pupate, with the moths emerging 10-14 days later. Female moths have a tan-colored body and white to cream-colored wings. Females have a 2-inch wingspan. European gypsy moth females cannot fly; Asian gypsy moth females are capable of flight. Male gypsy moths are smaller than females, with a 1.5-inch wingspan. The males are darker colored and have feathery antennae. Both have distinctive markings on the wing: an inverted V shape that points to a dot on the wings. The gypsy moth has one generation per year.

Early detection and rapid elimination of infestations in Nevada have prevented large infestations of gypsy moth from developing. States with infestations have found the following control measures useful:

White satin moth caterpillar. Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org.

Gypsy or Spongy Moth caterpillar. USDA Forest Service- Region 8 - Southern, USDA Forest Service, Bugwood.org.

Gypsy moth female (white) and male (gray). USDA APHIS PPQ, Bugwood.org.



Typical flowering plant
plant-care.com

- Mass trapping with pheromone-baited traps.
- Release of sterile male gypsy moths.
- Mating disruption with a registered synthetic version of the pheromone disparlure in products such as Disrupt®II, Luretape Gypsy Moth®, and Luretape Plus®.
- Diflubenzuron (Dimilin®), an insect growth regulator.
- *Bacillus thuringiensis kurstaki* (Btk), a microbe that is a natural disease agent of caterpillars. Several registered Btk products are available for use.

For more information on Gypsy or Spongy moth go to:
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5187452.pdf

https://www.fs.usda.gov/foresthealth/docs/fidls/FIDL-162-SpongyMoth.pdf

Identification of Common Landscape Pests and Beneficial Organisms in Nevada: https://naes.agnt.unr.edu/PMS/Pubs/2006-4051.pdf

Pollinator Protection: When growing crops for seed or adjacent to areas of seed production, it is vitally important to be aware of the effect that an application of pesticides will have on the pollinators of the crop. The three most important pollinators in Nevada are the alfalfa leafcutter bee, the alkali bee and the honeybee. If an application of pesticide is to be made near hives or domiciles, the owner of the bees should be notified so protective measures can be taken. For information on Nevada's Managed Pollinator Protection Plan go to https://agri.nv.gov/uploadedFiles/agrinvgov/Content/Plant/Entomology/nevada_pollinator_protection_plan_final.pdf.

Weeds Pests in Agricultural Plants

General information on weeds is covered in the General Knowledge: General Pest Problems chapter of this manual. Please refer to that chapter for discussion on the stages of plant development and the different plant life cycles.

It is impossible to describe and discuss every weed you may encounter in Nevada in this publication. However, it is imperative to identify the weed, its lifecycle, and its stage of growth, in order to formulate a weed management plan. There are many resources available to help you identify weeds. The Nevada Department of Agriculture and the University of Nevada, Reno Extension can help in identification. Many books contain pictures and descriptions of weeds. There is a limit to the amount of information they contain, so it is best to consult sources specific to your geographic area.

There is great variability in Nevada's climate. Weeds found in southern

Nevada can be much different than those in northern Nevada. Not all weeds that occur in the Las Vegas area occur at Lake Tahoe, and vice versa. There is a wealth of information available on weed identification on the Internet, but use caution and only trust information from reputable sources.

It is important to understand some of the living dynamics of plant growth to understand how herbicides work and the different ways they may affect plants. Plants consist of roots, stems or trunks, and leaves. Water movement in most plants is from the roots upward through the trunk or stem and into the leaves, where transpiration begins. Plants produce their own food or carbohydrates through photosynthesis. Movement of the food is from the leaves downward through the trunk or stem to the roots.

Weed control strategies

Most effective weed management plans include two or more control strategies. Weed control can be split into five separate categories.

- **Prevention:** Prevention includes factors such as using certified weed-free seed, hay, transplants, amendments, and mulches. Cleaning equipment to prevent the spread of weed seed and weed plant parts from one area to another is another prevention tactic. Prevention also includes removing weeds before they can form seed heads or spread by other methods. It is more difficult to prevent weed seeds from blowing in from an adjoining property.
- **Cultural controls:** Cultural controls are management practices that reduce the incidence of weed infestations. Cultural controls include using proper planting times and planting rates, planting companion crops, managing fertilization and irrigation to favor desired plants rather than weeds, rotating crops, and planting cover crops.
- **Mechanical/Physical controls:** These include tillage, hoeing, mowing, flooding, burning, hand-pulling, etc.
- **Biological controls:** This method uses a living organism to control a pest. Success depends upon selectivity, reproduction, adaptation, and ability of the organism to reach a high level of effectiveness.
- **Chemical controls:** Chemical control is the use of pesticides (in this case, herbicides) against a target pest (weeds). Many herbicides are available. In order to be effective, an herbicide:
  - Must come into contact with plant parts (leaves, stems, trunks, roots, etc.).
  - Must remain on the plant surface long enough to penetrate or be absorbed.
  - Must reach a living site to disrupt a vital process or structure.
  - Must be able to kill the target weed.

Successful weed management considers all the potential control methods available:

- **Prevention**
- **Cultural**
- **Physical / Mechanical**
- **Biological**
- **Chemical**

To be effective, herbicides must reach a living site to disrupt a vital process or structure.

For the latest noxious weed listing, go to http://agri.nv.gov/Plant/Noxious_Weeds/Noxious_Weed_List/

Nevada's Noxious Weeds

A noxious weed is a plant that has been defined as a pest by law or regulation. This designation requires that landowners or occupiers control noxious weeds growing on their property. If a plant is found to be detrimental or destructive and difficult to control or eradicate, the Nevada Department of Agriculture can recommend to the state board of agriculture that the plant be designated as noxious. Nevada's noxious weed list can be found at http://agri.nv.gov/Plant/Noxious_Weeds/Noxious_Weed_List/.

For help identifying noxious or other problematic weeds, contact the Nevada Department of Agriculture, 775-353-3600, or the University of Nevada, Reno Extension, 775-784-4848. The following publications may help in identifying noxious weeds: Nevada Noxious Weed Field Guide, available by weed name at the University of Nevada, Reno Extension website at https://extension.unr.edu/program.aspx?ID=15 (scroll down and click on the weed you are interested in) and Nevada Nuisance Weed Field Guide, https://naes.agnt.unr.edu/PMS/Pubs/1399_2019_01.pdf. Hard copies of both of these publications are available at most University of Nevada, Reno Extension offices throughout the state.

Plant Diseases in Agricultural Plants

There are six major principles of plant disease management:

- Exclusion
- Eradication
- Protection
- Resistance
- Therapy
- Avoidance

These six principles are discussed in detail in the General Knowledge: General Pest Problems section of this manual.

Successful plant disease management considers all the potential control methods; this is called Integrated Pest Management or IPM. The potential control methods are:

- Prevention
- Cultural controls
- Physical or mechanical controls
- Biological controls
- Chemical controls

Most plant disease management plans combine two or more control methods.

IPM is discussed in detail in the General Knowledge: Integrated Pest Management (IPM) chapter of this manual.

Most plant disease management plans combine two or more control methods. Chemical control in agricultural plants can be achieved through seed treatments, soil treatments and/or treatment of growing plants.

A disease is defined as any impairment of plant health or a condition of abnormal functioning.

Selected Cultural Practices for Managing Plant Diseases in Nurseries and Greenhouses

- Become familiar with the common diseases of nursery and greenhouse plants. Act quickly to eliminate them.
- Inspect all plants brought on the premises, and refuse to accept diseased plant materials.
- Provide good air circulation around plants.
- Avoid excessive humidity.
- Use soil that is pasteurized or otherwise pathogen free.
- Choose disease-resistant plant varieties.
- Select plants that are well-adapted to Nevada's climate.
- Avoid injuring plants.
- Practice good sanitation.
- Control weeds.

Specific Diseases in Agricultural Plants

Nevada cropland exceeds 600,000 acres. Crops include:

- Alfalfa hay and alfalfa seed
- Potatoes
- Small grains
- Onions and garlic
- Fruits and vegetables

Specific diseases related to each of these crops are discussed below.

Alfalfa Hay and Alfalfa Seed: Disease management in alfalfa hay production is largely based on cultural practices to reduce loss, such as variety selection and the use of certified weed-free seed. Many of the diseases mentioned below are favored when soils are heavy and poorly drained. Excessive soil moisture can allow soil-borne fungal or bacterial diseases to develop. Additionally, dodder and nematodes can cause damage to plants and may create entry sites for diseases. Some seed is treated with fungicides to control damping-off disease during seed germination and plant

Alfalfa

establishment. In many cases, adapted resistant alfalfa varieties are available to combat many of the major alfalfa plant diseases.

Alfalfa seed production is also complicated by dodder. Dodder seeds are similar in size and shape to alfalfa seeds, so producing weed-free seed can be difficult if dodder is present in the field.

Alfalfa root diseases include:

Phytopthora root rot occurs most often in soils with poor drainage or where water stands for an extended amount of time.

- ***Phytophthora* root rot:** The fungus causing this disease is present in the soil, where the disease can build up. It occurs most often in soils with poor drainage or where water stands for an extended amount of time. It is common at the tail end of flood-irrigated fields, where water collects. Symptoms include stunting and yellowing of the above-ground portions of the alfalfa plants. The plants may wilt due to inadequate water uptake resulting from root damage. The roots may be brownish or dead. Control: Manage irrigation properly, level fields, rotate crops and plant resistant varieties.
- **Fusarium root and crown rot:** The disease occurs in most soils. Infection can become more severe in the presence of nematodes, which cause injury to the plant and provide an open wound for the infection to enter the plant via the roots. Mechanical injury by surface traffic can cause injury to the crowns, allowing the disease to enter. Control: Plant resistant varieties, maintain favorable growing conditions for the plants to reduce stress, reduce surface injury and control nematodes.
- **Bacterial wilt:** This bacterial disease occurs in most soil types but is more common in cold climates. It can be severe in the presence of nematodes or other root-feeding insects that create entry sites for the disease. Symptoms include stunting of the plants and yellowish to brown discoloration inside the root. Control: Plant resistant varieties. Cultural practices that limit damage and maintain favorable growing conditions can limit the infestation. Control nematodes or other root-feeding insects.

Damping off is caused by several soil-borne fungi.

- **Damping-off of seedlings:** Caused by several soil-borne fungi. This disease causes seedlings to rot at the soil surface. Seedlings that survive are stunted and yellowish. The fungi causing this disease can be transported by water, by contaminated equipment, and by movement of infected plant materials. Disease is favored in cool temperatures, excessive moisture, low light or improper fertilization. Control: Plant during conditions that favor rapid germination and seedling growth. Control irrigation and fertilization. Use seed treated with fungicide to

protect seedlings from damping off. As these diseases have a wide range of hosts, crop rotation is not an effective cultural control.

- **Nematodes:** These microscopic roundworms live in the soil and feed on alfalfa roots. They cause stunting of plants and/or galls on the roots. Infestation can be localized to a small area of the field or extensive throughout the field. Infestation by nematodes can increase the incidence of other diseases, as their feeding causes root damage, providing an entry point for disease. Control: Planting resistant varieties and rotating crops can aid in control. Pre-plant soil fumigation can be effective but is expensive. There are no non-fumigant nematicides currently registered for use on alfalfa. Using a soil fumigant requires an additional certification in Category 5: Soil Fumigation.

Alfalfa foliage diseases include:

- **Common leafspot:** As the name implies, this fungal disease causes numerous small (1-3 mm), brown to black spots on infected leaves. The spots are roughly circular, and the margins of the spots can be toothed or smooth. As the disease progresses, the leaves eventually become yellow and die. Infection of established plants is seldom fatal, but the disease can be fatal to seedlings. The disease is favored in cool to moderate temperatures and wet conditions. It can be a problem in the first and second cuttings. The pathogen overwinters in undecayed plant residue and germinates when moisture is present. The windblown spores can infect the lower leaves of the plants directly through the leaf cuticle. Control: Harvest the first cutting early to reduce the severity of the disease in the field over time. Some cultivars may be more resistant than others. Crop rotation and good sanitation can reduce the amount of fungal inoculum.
- **Spring blackstem:** This fungal disease affects both leaves and stems of alfalfa plants. It is a cool-season disease that overwinters in plant debris and is spread by water or infected plant materials. Symptoms are small black to brown spots on leaves and stems. The spots are irregular to triangular in shape. The affected leaves turn yellow and wither before falling off. The affected stems turn black near the base of the plant. Most damage occurs before the first cutting. Control: Plant resistant cultivars, plant pathogen-free seed, and cut early to reduce leaf loss. Good sanitation and crop rotation can reduce the amount of fungal inoculum.
- ***Stemphylium* leafspot**: This fungal disease is a cool-season foliar disease. Moist conditions favor infection and disease spread. Symptoms include irregularly shaped lesions on leaves that have tan centers with a darker border. Defoliation can occur, but generally only under very heavy disease pressure. The disease is spread by spores via water or wind. This

Nematodes are microscopic roundworms that live in the soil and feed on alfalfa roots.

Common leafspot is favored in cool to moderate temperatures and wet conditions. It can be a problem in the first and second cuttings of alfalfa.

Downy mildew is another fungal disease that favors cool, wet climate conditions.

Dodder is a parasitic plant that attaches to and eventually kills its host plant.

Potato

disease is usually found in the first and second cuttings. Control: Early harvest is an option with severe infestations. Some cultivars may have more resistance than others, but seed companies do not commonly report resistance to this disease.

- **Downy mildew:** This is another fungal disease that favors cool, wet climate conditions. The upper surfaces of the leaves become lighter in color. Entire buds and leaves may become infected, becoming distorted and yellowing. Infected leaves can fall off the plant, reducing quality and yield of the alfalfa. This disease is usually only a problem in the spring. Spring-planted fields can be severely affected, as this is when the disease is most common and the field is in the seedling stage. Stand survival is usually not affected. Control: Early harvests can be used to reduce losses. Resistant cultivars are available.
- **Dodder:** Dodder is a parasitic plant that attaches to and eventually kills its host plant. The plant appears as a yellow, stringy mass on infected plants. In alfalfa fields, it can be a real nuisance, since the seeds can remain viable in the soil for many years, sprouting and causing new infestations during multiple growing seasons when conditions are right. Control: Dodder reproduces from seed, so it is essential to prevent production of seed. Remove infested plants. For existing stands, preemergence herbicides may help control germinating dodder. Dodder seed can be spread by equipment and livestock. Use certified weed-free seed. Crop rotation using non-host plants, such as grasses, can interrupt the infestation cycle.

Potatoes: Potatoes are another important crop in Nevada. Potato varieties are generally chosen for agronomic characteristics, not disease resistance. All diseases discussed below can be managed by destroying cull piles as the final sanitation practice in the fall. This will reduce the source of spring inoculum of many potato diseases.

Foliage diseases of potatoes

- **Late Blight** is a fungal disease that is most severe during cool, clear weather. It occurs in fields with sprinkler irrigation systems, where moisture levels are high. It first appears as small light to dark green water-soaked spots, often with a yellowed halo. Lesions enlarge rapidly and turn brown. The lesions are not restricted by leaf veins. Control: Some cultivars are more resistant than others. Crop rotation can reduce the incidence of the disease. Foliar fungicide applications can be used to manage the disease.
- **Early Blight** is a fungal disease that occurs during high humidity conditions. Although it appears early in the season, it spreads later in the

growing season, and is a problem late in the growing season. Early blight also produces lesions on the leaves. The lesions form on the lower, oldest leaves first and have a bullseye or target pattern. As the lesions grow and coalesce, they are restricted by large leaf veins and may appear more angular. The disease appears to increase on plants that are stressed from poor nutrition, so higher rates of nitrogen may help control the disease. Irrigation in cool, cloudy periods or late in the evening when foliage may remain wet for extended periods should be avoided. Control: Some cultivars are more resistant than others. Foliar fungicide applications can be used to manage the disease.

- **Black Leg** is a bacterial disease that occurs on the stem and on the potato tubers. Stems infected with black leg usually have a black decay that begins at the underground seed piece. Leaves of infected plants often roll upwards, yellow and wilt. Plants are stunted and appear stiff before wilting and dying. Mechanical injury of plants by cultivation increases the incidence and severity of the disease. Control: Certified seed will significantly reduce the incidence of Black Leg. Seed treatment may also be required. Remove infected plants to limit the spread of the disease. Avoid injury during harvest and storage. No chemical control measures are available to date.
- **Calico Virus** in potatoes is caused by the same virus that causes alfalfa mosaic disease. Leaves may roll up and appear yellowed. Plants may appear stunted. Control: Aphids are vectors of this virus, so controlling aphids will help control the disease. Use certified seed, remove all infected plants immediately, control volunteer plants, and destroy all cull piles. Avoid planting potatoes near alfalfa.

Root and Tuber Diseases of Potatoes

- **Verticillium Wilt** is a fungal disease that plugs the water-conducting tissues, causing premature yellowing and death of the foliage. Tan discoloration of the vascular tissues in cut stems of infected plants is common. This fungus invades through the root system, through root hairs and wounds. The wound can be the result of mechanical injury or may be caused by insect or nematode injury. Control: Crop rotation (four to six year cycle), planting resistant cultivars, controlling insects and nematodes, and good sanitation will help control this disease. Soil fumigants can be used in infected fields.
- **Scab** is a fungal disease that results in corky lesions on the tuber that may be superficial or may cause deep pits. The scab disease can survive on decaying plant debris and can be spread by water or contaminated

Destroying all cull piles as the final sanitation practice in the fall will help to control all the potato diseases discussed here.

Calico Virus in potatoes is caused by the same virus that causes alfalfa mosaic disease.

Verticillium Wilt is a fungal disease that plugs the water-conducting tissues, causing premature yellowing and death of the foliage.

Smuts are the major disease problem for small grains.

Onions

The major disease problems of onions and garlic are fungal diseases.

soil on equipment. The lesions are usually circular but can coalesce in the later stages to form irregular shapes. A soil pH of 5.5 to 7.5 is most favorable to scab. Scab is most severe when tubers develop under warm, dry soil conditions, so avoid moisture stress during the two to six weeks following tuber formation. Control: Rotate crops, plant certified seed, treat seed, plant resistant cultivars, and practice good sanitation.

- **Root-Knot Nematode** causes stunted plants and rough, pebbly-appearing tubers. Additionally, the injuries these worms create provide a pathway for other diseases. Control: Certified seed, crop rotation, seed treatment and good sanitation will help control nematodes. At present, there are no nematode-resistant potato varieties available.

Small Grains (wheat, barley, oats, sorghum, etc.): Smuts are the major disease problem for small grains. Smuts are fungal diseases that are carried in the seed. Smut does not show up until the seed heads form. Diseased plants have darkened, discolored seed heads and are commonly stunted. Control: Certified seed, planting resistant cultivars and seed treatment will help control smuts.

Onions and Garlic: Onions and garlic are important crops produced in Nevada. The major disease problems are fungal diseases. Insects, nematodes, and other pests that feed on onions and garlic can cause wounds that provide entry for the fungal diseases.

- ***Botrytis* neck rot** is a common fungal disease of onions and, to a lesser extent, garlic. The fungus causes considerable losses during field curing periods and during storage. White globe varieties of onions are very susceptible to the disease. The fungus persists on dead onion and garlic plant tissues for long periods and germinates in moist, cool weather. Control: Cultural practices will help limit the incidence of infection. Do not fertilize with excessive amounts of nitrogen, as this will delay maturity. Limit irrigation late in the season. Always allow time for adequate and proper curing. Store properly, ensuring low temperatures and humidity and good air circulation.
- **Pink Root** is a fungal disease that affects onions. As the name implies, the most striking symptom of this disease is pink roots. Roots eventually shrivel, turn black and die. The fungus is very common in the soil and can penetrate roots directly. No wound is necessary for an infection to occur. Stressed plants are more susceptible. The fungus can remain viable in the soil for long periods (10 years or more) and can be spread by water and by dirty equipment. Control: Prevention and control include use of resistant varieties, good soil tilth and fertility, control of other diseases and insects that will stress plants, good sanitation, and cleaning

equipment between fields. Crop rotation will reduce the incidence of infection but will not eliminate it entirely. Pre-planting soil fumigation is effective for control. Soil fumigation requires and additional certification in Category L3: Soil Fumigation.

- **White Rot** is a fungal disease that affects both onions and garlic. The leaves of infected plants start to decay at the base, yellowing, wilting, and toppling over. The older leaves are affected first. The roots rot and plants are easily pulled from the soil. A fluffy white growth, the fungal mycelium, may be present on the remaining roots and the base of the bulbs. This fungus can remain viable in the soil for 20 years or more. The disease can be spread from field to field by flood water, on equipment or on plant material. Control: Avoidance and good sanitation are effective controls. Once a field is infected, chemical treatments are necessary to produce onion and garlic crops. Soil fumigation provides good control.

Fruits and Vegetables: Nevada grows fruit and vegetable crops, such as grapes, apples, pears, cantaloupe, tomatoes, squash and herbs.

- **Powdery Mildew** is a common problem on many fruits and vegetables in Nevada. Symptoms are a powdery mycelium and spores on all foliage. Control: This fungal disease is best controlled with various copper and/or sulfur formulations.
- **Fireblight** is a common problem in apple and pear production. It is a bacterial disease that is spread by pollinators and rain splash. It first appears in the blossom clusters as wilting and collapse of the cluster. Diseased tissue produces brownish, sticky exudates. The tips of the infected, young succulent growth shoots curve into a characteristic shepherd's hook and appear to have been burnt. Warm, wet spring weather is ideal for disease development. Control: Remove diseased plant parts and prune to healthy wood. Dispose of infected plant materials. Use streptomycin or copper spray formulation during bloom to help prevent infestation.
- **Fusarium Wilt** is a fungal disease that can affect cantaloupe. It causes root rot and wilt as the plant develops, generally after fruit set. Plants may develop a yellow runner on one side of the plant followed by rapid wilting of the infected runner. Other runners begin showing symptoms and the whole plant can collapse. In soils where the inoculum is high, seedlings may wilt. The disease is long-lived in soil and can remain viable for 20 years or more. Control: Good sanitation, planting resistant varieties, and cleaning equipment between fields can help reduce the infestation. Seed treatment can also be effective for control.

Pear, Apple

Melon

Tomatoes

Chemigation is the application of agricultural chemicals, both pesticides and fertilizers, through an irrigation system.

Chemigation may save time (labor) and money by reducing the need for personnel and equipment.

- **Curly Top Virus** is a disease that affects tomatoes in Nevada. This disease is transmitted by leafhoppers, which carry the disease for life. Leafhoppers have a wide range of hosts. Plants with curly top stop growing and become stunted. The plants turn yellow or bronze in color, and leaves may have a purple tinge. The plants become stiff and soon die. Leafhoppers tend to feed on the plants that border bare soil areas, so the edges of the field are most susceptible. Control: Dusting transplants as soon as they are set out and as new foliage appears, until fruit set, will discourage leafhoppers. Talc, diatomaceous earth, or finely ground pumice are equally effective. There are no curly top resistant varieties of tomato to date.

Chemigation

Chemigation is the process of applying agricultural pesticides through floods, drips, sprinklers, and other types of irrigation systems. Applications of pesticides through an irrigation system requires thoughtful planning, specialized equipment, and additional safety measures to protect applicators and co-workers and also protect water resources. For information on calibrating your chemigation equipment, see “Calibration of Chemigation Equipment” under the “General Knowledge: Guidelines for the Safe Use of Pesticides” section of this manual.

Advantages of pesticide chemigation: Chemigation offers several distinct advantages in comparison to conventional application methods.

- Soil compaction is avoided, as heavy spray equipment never enters the field.
- Crops are not damaged by root pruning, breaking of leaves, or bending over the shoots, as occurs with conventional spray equipment and techniques.
- Less equipment may be required to apply the pesticides.
- Less energy is expended in applying the chemical, as vehicles do not have to traverse the field.
- Less labor is needed to apply and supervise the pesticide application.
- Capitol, maintenance, and labor costs are reduced.
- The application of pesticides can be more carefully regulated and monitored.
- Pesticides can be applied quickly before a disease or insect infestation spreads.
- Pesticides can be more evenly distributed throughout the target site, preventing "skipping" through the field.

- Pesticides can be applied to the crop or soil when crop or soil conditions would otherwise prohibit entry into the field with conventional spray equipment.
- Requires less mixing and loading, reducing applicator exposure.

Disadvantages of pesticide chemigation:

- Specific safety precautions, specialized equipment and training are required for chemigation.
- The initial cost of equipment is high, but with long-term use there may be significant savings in labor and other equipment costs.
- Potential for contamination of water sources is higher with chemigation than with other pesticide application methods.
- Some pesticides are not approved for application through chemigation systems.

A major drawback of chemigation is the increased potential for contamination of water sources. Because irrigation water, livestock water and domestic water may come from the same source, it is essential that applicators using chemigation comply with specific rules to protect water sources.

Protecting the environment is an essential requirement of all pesticide applications, and chemigation is no different. Water and pesticides are applied through sprinkler systems for most chemigation applications in Nevada. Groundwater is the most frequently used water source in many locations. Water used for chemigation is pumped from a groundwater well and applied directly through a sprinkler system. Groundwater may also be pumped into a ditch or canal and then pumped out of the ditch into a sprinkler system. Surface water sources, such as rivers or streams, may be diverted into irrigation ditches where water can be pumped into a sprinkler system. All water sources must be protected, regardless of the origin.

After pesticides are applied, they are eventually broken down by sunlight and chemical or microbial activity. If pesticides reach the groundwater, they will be broken down very slowly due to low temperatures, absence of sunlight and lack of microbial activity.

Some pesticide labels do not allow for application by chemigation. For products that do allow application by chemigation, specific instructions will be listed on the label. Many of the instructions are related to backflow hardware that must be installed in the chemigation system. To protect water resources, applicators must read and carefully follow all chemigation requirements on pesticide labels.

Specific safety precautions, specialized equipment and training are required for chemigation.

Potential for contamination of water sources is higher with chemigation than with other pesticide application methods.

Some pesticide labels do not allow for application by chemigation.

For products that do allow application by chemigation, specific instructions will be listed on the label.

Chemigation requires that two separate hardware systems be joined together: the chemical injection system and the irrigation system. Properly functioning anti-pollution devices must be correctly installed in both systems to effectively prevent groundwater contamination.

Chemigation and Irrigation

Fertilizers have been applied through many types of irrigation systems for many years. With the introduction of center pivots and linear move (wheel line) irrigation systems, the application of various pesticides has become more widespread. Significant advancements have been made to the designs of equipment to enhance chemigation, including under-canopy spray heads to apply insecticides to the under sides of leaves and high-speed gearboxes for the drive units. This enables the irrigation equipment to move faster across the field for a light application of pesticide(s). Center pivots and linear moves have peculiar traits that affect pesticide application that are not common to other irrigation methods. They do not require the presence of people in the field during irrigation. They are capable of quick, small, and very uniform applications of water and therefore pesticides. Furthermore, these systems wet the leaves of the crop that surface (flood or furrow) irrigation does not.

The use of micro-irrigation, including drip irrigation, has boomed in the last few years. This has stimulated a parallel growth in the use of chemigation. An increasingly wide range of fungicides, herbicides and insecticides are injected through micro-irrigation systems in the United States.

Chemigation Safety Hardware

Chemigation requires that two separate hardware systems be joined together: the chemical injection system and the irrigation system. Properly functioning anti-pollution devices must be correctly installed in both systems to effectively prevent groundwater contamination.

The devices listed in table A.1 are intended to protect water sources from pesticide contamination. They are listed on labels of pesticides that are approved for chemigation and must be installed on systems that are used to chemigate those products.

The U.S. EPA has approved a list of alternative chemigation safety equipment that can be used in the place of specific equipment as required by pesticide labeling (Table A.2). Any chemigation equipment that is required on pesticide product labeling but has no listed alternative(s) is still required as a component of the chemigation system.

Protecting the water supply from contamination should be a top priority when setting up pesticide injection equipment. Without the proper safety equipment discussed above, any of the following scenarios may occur:

1. An unexpected shutdown of the irrigation pump could cause concentrated pesticides and water to be drawn into the well and aquifer.

2. The irrigation pump shuts down while the pesticide injection pump continues to operate. This can cause pesticides to backflow into the well and groundwater supply, or force high levels of pesticides to flow into the irrigation pipe and distribution system, damaging the crop and environment.
3. The pesticide injection system stops while the irrigation pump continues to operate. This causes water to backflow through the pesticide supply tank and overflow onto the ground.

Description of Chemigation Safety Devices

Check Valves and Vacuum Relief Valves: Check valves and vacuum relief valves (anti-siphon devices) are required on the irrigation pipeline. They keep water and/or pesticide and water from backflowing or siphoning back into the irrigation water source should the irrigation pump shut down. Both of these valves must be located between the irrigation pump outlet and the point of pesticide injection. The check valve must have a positive closing action and a watertight seal. It should be easy to repair and maintain. The vacuum relief valve allows air into the pipeline when the water flow stops, preventing the creation of a vacuum that could lead to siphoning.

Check valves and vacuum relief valves (anti-siphon devices) keep water and/or pesticide and water from backflowing or siphoning back into the irrigation water source should the irrigation pump shut down.

A second backflow device, in addition to or in place of, a normally closed solenoid valve in the pesticide injection line is needed for two purposes: 1) to prevent the water from flowing into the pesticide supply tank when the pesticide injector is shut off, and 2) to prevent gravity flow from the pesticide supply tank into the irrigation pipeline after an unexpected shutdown. The backflow device is required to be spring-loaded and have a minimum of 10 psi cracking pressure. This device is generally preferred by growers throughout the United States over the normally closed, solenoid-operated valve located on the intake side of the injection pump. Several manufacturers sell a combination check valve/injection port device that is located at the discharge end of the chemical hose. This combination device provides the safety feature required by EPA and also places the pesticide into the midstream of the irrigation water flow, which provides better chemical mixing.

Low-Pressure Cutoff: Low-pressure cutoff turns off the power to the injectors in the event the water pressure drops in the main irrigation line.

Low-Pressure Drain: An automatic low-pressure drain is used for monitoring check valve performance. This device should be placed on the bottom side of the irrigation pipeline. If the main line check valve leaks slowly, the water or pesticide and water will drain away from, rather than flow into, the water supply. The location of the drain should be at least 20 feet from the well, between the irrigation pump and the main line check valve. In some cases,

The following sketch shows a chemigation layout that includes the United States Environmental Protection Agency's (EPA) required safety devices.

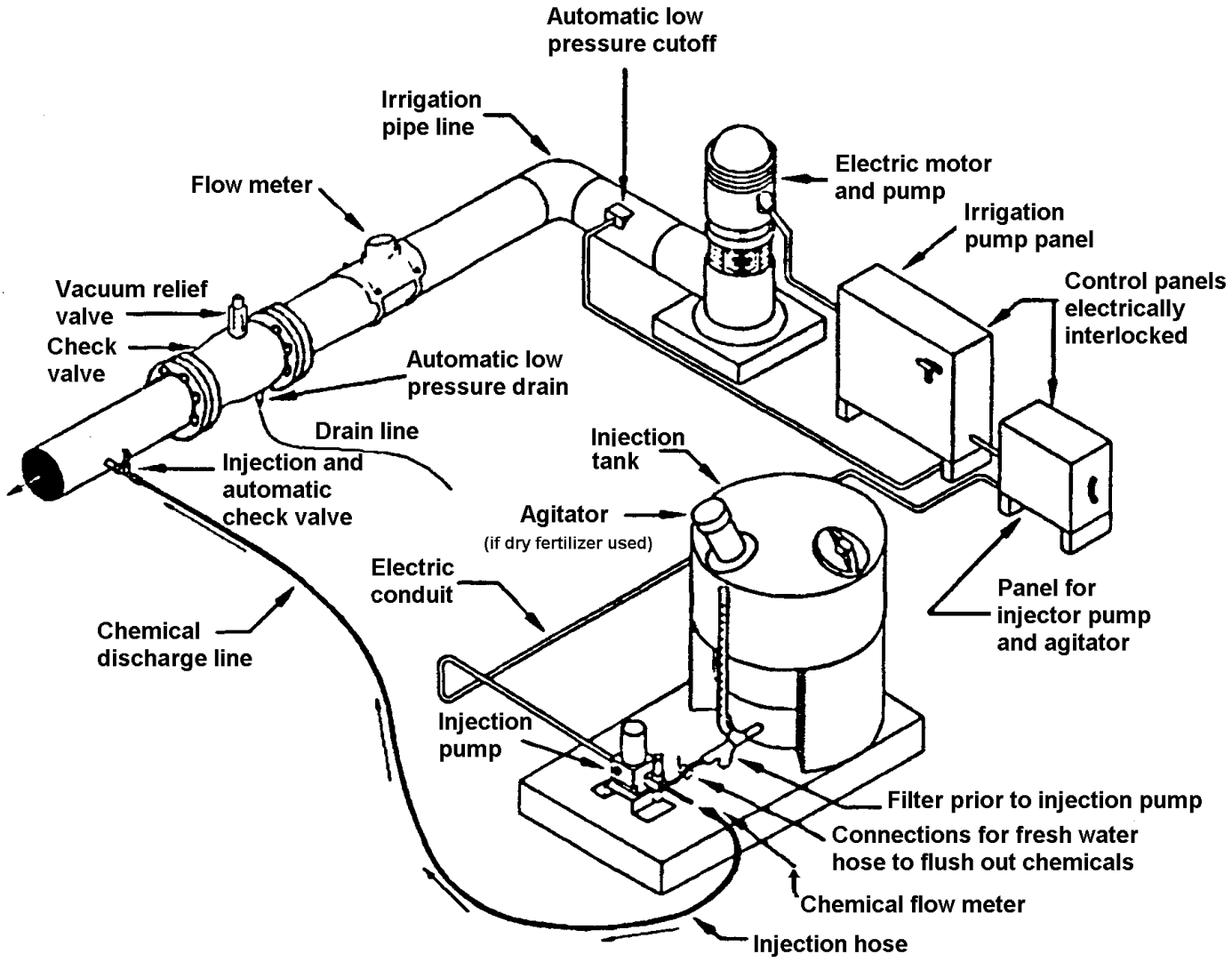


Table A.1. Description of required safety devices

Devices	Description/Location	Purpose
Irrigation check valve*	Between well and injection points	Prevents pesticide from flowing backwards and entering the water source
Injection line check valve	At the injection point. A one-way valve with a 10 psi spring that closes when not under pressure	Prevents water from flowing backwards into the chemical tank, causing the tank to overflow
Vacuum relief valve	Between the check valve and the well	Prevents a vacuum when pump shuts off; reduces chance of backflow
Low pressure cutoff	On irrigation pipeline	Turns off injector power when irrigation water pressure is low
Low pressure drain*	Between well and irrigation line check valve	Discharges any water that might leak through the check valve after irrigation pump is shut off
Normally closed solenoid valve*	Between injection pump and pesticide tank	Prevents tank from emptying unless injector is working
Interlock	Between injection pump and irrigation pump panels/power	Prevents injection if irrigation pump stops

**These devices may be replaced with an alternative device listed in Table 1A.2.*

Table A.2. Approved alternative devices for chemigation equipment.

Original Device	Approved Alternative Device
Normally closed, solenoid-operated valve located on the intake side of the injection pump	Spring-loaded check valve with a minimum of 10 psi cracking pressure Normally closed, hydraulically opened check valve Functional vacuum relief valve located in the pesticide injection line between the positive displacement pesticide injection pump and the check valve.
Functional main water line check valve and main water line low pressure drain	Gooseneck pipe loop located in the main water line immediately downstream of the irrigation water pump
Positive dis placement pesticide injection pump	Venturi system including those inserted directly into the main water line, those installed in a bypass system, and those bypass systems boosted with an auxiliary water pump
Vacuum relief valve	Combination air and vacuum relief valve

Chemigation safety devices must ensure that if the irrigation pump stops, the pesticide injection also stops.

Each pesticide label must state that the pesticide product can be chemigated. Applicators must adhere to the instructions provided on the pesticide container labels.

Inspect hoses regularly for leaks and cracks.

Low-Pressure Drain continued: placement of the valve may be more feasible downstream of the main line check valve. However, it should always be placed on the irrigation pipeline before the point of injection.

Solenoid Valve: A normally closed solenoid valve can be electrically interlocked with the engine or motor driving the pesticide injection pump. This valve, located on the inlet side of the injection pump, provides a positive shut-off on the pesticide injection line. Neither the pesticide nor the water can flow in either direction if the pesticide pump stops .Interlock: Electrical interlock connects the irrigation pump to the chemical injection device, so in the event of an irrigation pump failure, the pesticide injection pump will also stop. This prevents the pesticide from being pumped from the supply tank into the irrigation pipeline after the irrigation pump stops.

For internal combustion engines, the pesticide injection pump can be belted to the drive shaft or an accessory engine pulley. Other possibilities include operating the injection pump from the engine electrical system (12-volt). **In all cases, it is essential that if the irrigation pump stops, the pesticide injection also stops**. In addition to interlocks, additional protection is provided by a low-pressure shutoff switch that turns off the pump should water pressure drop and the pesticide is no longer being applied at label rates. This switch triggers all other pumps to shut off.

Pesticide Labels

Labels for pesticides that are chemigated must provide detailed information regarding application rates, re-entry intervals, personal protective equipment, and clothes, etc. **Each pesticide label must state that the pesticide product can be chemigated and applicators must adhere to the instructions provided on the pesticide container labels**. Chemicals are registered in each state for specific crops and methods of application.

Appropriate Materials for Hardware

Hoses: In most cases, hoses should be constructed of reinforced braided Ethyl Vinyl Acetate (EVA). EVA is:

- Flexible at a wide range of temperatures.
- Capable of working at pressures up to 200 psi.
- Stable under UV radiation. It does not deteriorate after prolonged exposure to sunlight.
- Chemically compatible with pesticides.
- Available in thicknesses that work under suction without collapsing.

Inspect hoses regularly for leaks and cracks. Flush hoses and injection equipment at the end of every injection with clear water. When hoses and

chemigation equipment are not in use, cover them with a tarp or similar material.

Fittings: When injecting pesticides into an irrigation system, the material of choice is generally 316 stainless steel, as some pesticides can destroy PVC fittings. To be safe, contact the manufacturers of both the pesticide and the injection equipment to determine compatibility of the pesticide being injected with the equipment being used and the potential for corrodibility or other adverse chemical reaction.

Tanks: **Avoid mild steel tanks!** Construct tanks of poly or fiberglass, as mild steel can corrode. If stainless steel is used, it should be constructed of 316 stainless. There should always be an on/off valve attached to the tank itself so that the injection mechanism can be removed. An easily cleaned 40 to 80 mesh filter should be attached downstream of the on/off valve.

Containment Structures: If a pesticide could potentially be hazardous in the event of a spill, it is recommended the chemical tank be located within a containment structure. A containment structure may simply be a larger poly tank that essentially acts as a "double-hulled" unit (a chemical tank inside the poly tank), a containment unit constructed of cinder block walls around a concrete pad, or at the very least, a soil wall around the chemical tank.

Neatness: **Neatness counts!** For safety reasons, it is important to maintain a neat chemigation area. With a neat chemigation area, spills and leaks are easy to identify, isolate and correct. Messy chemigation areas encourage lax operation that is hazardous to the operator and the environment.

Chemical Safety: Always follow label instructions for safety. It is essential that the manufacturer's guidelines be followed when mixing fertilizers and pesticides together. Many fertilizers and pesticides cannot be mixed together or must be mixed in a certain order. If the manufacturer's guidelines are not followed, there is a potential for dangerous reactions.

Chemical Injectors: There are many ways to inject pesticides into irrigation systems. The choice of methods and equipment used depends on the individual operator's skills and preferences as well as initial and maintenance costs.

The following may need to be considered when choosing the way to inject pesticides:

- Differences between injecting liquids, such as flowable (F) products, suspended concentrates (SC), or emulsifiable concentrates (EC) versus injecting non-liquids, such as wettable powder (WP) or soluble powder

Flush hoses and injection equipment with clear water at the end of every chemical injection.

Construct tanks of poly or fiberglass, *not* mild steel. Mild steel has a greater potential for corrosion.

For safety reasons, it is important to maintain a clean chemigation area.

Always follow label instructions for safety.

There are many types of injectors on the market. Some require power, and others do not.

(SP) pesticides. Liquid pesticides may not need agitation or mixing in the field, whereas non-liquid pesticides require mixing and agitation.
- Wear on the system components. Non-liquid products increase wear to nozzles and valves compared to liquid materials.
- Potential hazards of the pesticide. All pesticides have special precautions to be followed, especially for worker safety.
- Availability of power.
- Portability versus permanent installations.

Injector types: There are many injectors on the market. Some require power, and others do not. Below are examples of different types of injectors that are available. Some injectors are specific to an irrigation method, such as drip, open ditch, center pivot, wheel lines and solid sets.

- In-line pressure differential
- Venturi bypass systems
- Bypass pumps
- Float valves (open canal or ditch)
- Differential pressure tanks
- Nitrogen gas powered pumps
- Nitrogen pressurized tanks
- Water powered pumps
- Diaphragm and piston pumps

Diaphragm pumps have been used in the chemical industry for many years but have only been actively marketed for chemigation during the last few years. The **advantages** of using diaphragm pumps over piston and venturi units are:

- They have a small number of moving parts.
- A limited area of the unit is exposed to the pesticide being injected.
- The design of the pump makes it easy to adjust the injection rate while the pump is running.

Piston pumps were the earliest available and actively marketed injection pumps for agricultural chemicals. Both single and dual piston units are available in a wide range of capacities. These types of pumps commonly have two distinct **disadvantages** for when used for chemigation:

- Piston pumps are subject to accelerated wear of the piston seals.
- Calibration of piston pumps is relatively time-consuming.

See “Calibration of Chemigation Equipment” under the “Guidelines for the Safe Use of Pesticides” section for information on calibrating chemigation equipment.

Special Considerations for Greenhouse Pesticide Applications

When you apply pesticides:

- Follow all label directions.
- Follow all requirements of the Worker Protection Standard.
- Before you start, consider the conditions in the greenhouse. Wait until later if you need to apply a pesticide to the leaves of plants that are wet from recent watering, as the pesticide might wash off the leaves without sticking.
- If watering is scheduled to start soon, do not apply a pesticide that could be washed off the treated surface.
- Carefully check and calibrate the application equipment. Make sure there are no leaks, all parts are working properly, and the application rate is accurate.
- If you need to fix the application equipment, turn it off first. Remember to keep your protective equipment on while you are fixing the equipment.
- Never apply pesticides in such a way that they can get on people, either directly or through drift.
- Check the area of the greenhouse where you will be working. Make sure no people or pets are nearby.
- You may be required by law to post signs at each entrance to the greenhouse area to be treated. Keep anyone not involved in the application out of the treated area during the pesticide application and during the restricted re-entry period.
- For some types of greenhouse applications, you must keep people out of an area that is larger than the area where you will be applying the pesticide.
- When applying a pesticide that does not require you to wear a respirator, but where you will be spraying fine droplets from a distance of more than 12 inches above the plants, you must keep people at least 25 feet back from the edges of the area while you are spraying. You also must turn off the greenhouse ventilation, or at least down to "low," so the airflow does not cause the pesticide to drift out of the target area.
- When applying pesticides from a lower height – 12 inches or less – using granules, dust, or a coarse-droplet spray, you do not have to use the 25-foot setback. People must stay out of the immediate treatment area, but

Consider the conditions in the greenhouse. Wait until later if you need to apply a pesticide to the leaves of plants that are wet from recent watering, as the pesticide might wash off the leaves without sticking.

Check the area of the greenhouse where you will be working. Make sure no people or pets are nearby.

You may be required by law to post signs at each entrance to the greenhouse area to be treated.

Keep anyone not involved in the application out of the treated area during the pesticide application and during the restricted re-entry period.

they can walk down nearby aisles or work at nearby benches while the application is taking place. The ventilation system may be left on during this kind of application. This is often necessary in a hot greenhouse to provide air circulation and cooling and prevent heat stress.

Vertebrate Pests in Agricultural Plants

Vertebrate pests are those pest animals that have backbones. Specific control measures vary for different species and are discussed individually in the General Pest Problems chapter of this manual.

Common vertebrate pest control practices

- **Exclusion:** Keep the pest out or away from crops by using barriers, such as fencing and row covers.
- **Sanitation:** Eliminate food and water sources. Store food and animal feeds, grain, and seed in rodent-proof containers. Repair leaky pipes.
- **Trapping:** There are several types of kill traps and live traps available for most vertebrate pest species. Choosing the proper trap and learning the correct way to use it is critically important. **Live trapping and releasing is not acceptable or legal.** Individuals who release live trapped animals are moving the pest problem, and sometimes diseases like rabies, distemper, or plague along with them. Live trapping followed by an approved method of euthanasia is recommended. The American Veterinary Medical Association has specific guidelines for euthanasia.
- **Repellents:** Repellents may be applied to valuable vegetation or can be used in areas where pests are known to frequent. They often don't work the way people expect them to work. Sunshine can break down the repellent, and sprinklers and rain can wash away the product. New growth on plants must be retreated and animals may simply get used to the repellent.
- **Rodenticide Baits:** Baits like seeds, grains and vegetation treated with rodenticides are used to control several types of vertebrate pests. Most baits must be applied in bait stations or underground within animal burrows to lessen the risk of killing of non-target species. Pesticide labels describe methods for applying the bait. Pesticides used include strychnine, zinc phosphide and various anticoagulants. Strychnine may only be applied underground.
- **Fumigants:** To purchase, apply or supervise the use of this pesticide, applicators must successfully pass the Category L2, Non-Soil Fumigation category exam.

Common vertebrate pest control practices:

- **Exclusion**
- **Sanitation**
- **Trapping**
- **Repellents**
- **Rodenticide baits**
- **Fumigation**

Fumigation requires certification in Category L2 Non-soil Fumigation.

Specific Vertebrate Pests: Please refer to the vertebrate pest section of the General Knowledge: General Pest Problems chapter in this manual.

Conclusion

Category A, Agricultural Plant Pest Control, is the category that covers pesticide applications on crops. This includes fruit and vegetable crops, small grain crops, feed crops, forage crops, nurseries, and greenhouses.

The growth of a single type of plant, also known as a monoculture, can provide an ideal setting for diseases, weeds, and animal pests to develop and thrive. Pesticides are often needed to reduce pests to tolerable levels, but they can have serious consequences if applied improperly. Pesticides can harm non-target plants, beneficial insects, wildlife, pets, livestock, and humans. Thoughtful planning and implementation are required to reduce pest pressure, minimize unintended damage, reduce costs, and maximize profit.

The first step in pest control is to correctly identify the pest. It is imperative to determine that the damage you see was actually caused by a pest. Consider all control options for managing the pest. Keep records of your management efforts and their success.

The first step in pest control is to correctly identify the pest. It is imperative to determine that the damage you see was caused by a pest.

Unless otherwise noted, all line drawings are from Clipart ETC, Florida's Educational Technology Clearinghouse, University of Southern Florida, http://etc.usf.edu/clipart/index.htm

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