AERIAL AND AGRICULTURAL GROUND MANUAL

VOLUME IX

July 2018

Pest Control Licensing Program
Plant Industry Division

Nevada Administrative Code (NAC) 555.280

Aerial and Agricultural Ground Fields and Categories

Aerial
Aerial refers to the use of aircraft, *including, without limitation, an unmanned aerial vehicle,* for the application of pesticides on standing or running water, rangeland, agricultural crops, forest, idle cropland and noncropland associated with the production of agricultural crops.

Aerial Categories
(1) Agriculture plant pests—the application of insecticides, miticides, acaricides, fungicides, bactericides and nematicides.
(2) Weeds—the application of herbicides, plant regulators, desiccants and defoliants.

Agricultural ground
Agricultural ground refers to the use of ground equipment for the application of pesticides on livestock, rangeland, agricultural crops, idle cropland and non-cropland associated with the production of agricultural crops.

Agricultural ground categories
(1) Agriculture plant pests—the application of insecticides, miticides, acaricides, fungicides, bactericides and nematicides.
(2) Weeds—the application of herbicides, plant regulators, desiccants and defoliants.
(3) Vertebrate pests—the application of various substances on agricultural ground for the control of vertebrate pests, including, without limitation, the use of fumigants for burrowing rodents. This category does not include the control of vertebrate pests in, on or around industrial complexes, institutional complexes, dwelling units or other structures designed for use by humans, or on ornamentals or turf in, on or around such structures.
(4) Soil fumigation—the use of various substances, including, without limitation, fumigants for the control of any pest in the soil at the time of treatment. This includes, without limitation, plant-parasitic nematodes, soil-borne pathogens, weeds and insects.

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INTRODUCTION

This manual covers the essential topics necessary to demonstrate proficiency for the Nevada Department of Agriculture's (NDA) Aerial and agricultural ground fields and categories pest control licensing programs. It is not meant to be a complete guide for agricultural pesticide applicators, but rather to serve as a general study guide for individuals preparing to take principal and/or operator examinations in one or more categories within these fields of pest control.

The chapters covering major Nevada pests on crops and rangelands, and control methods, have been extensively updated in this volume. Additionally, the manual now also includes several new topics, including chapters on:

- labeling of pesticides and chemical agents;
- worker protection standards (WPS);
- principles and approaches of integrated pest management (IPM);
- sampling procedures for proper pest identification and treatment;
- viruses, viroids, and mycoplasmas;
- specialized conditions and applications and
- the Nevada noxious weed program.

For additional information, consult the references and links provided at the end of each chapter and the "useful references" section at the end of this manual.

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CHAPTER 1: LABELING OF PESTICIDES AND CHEMICAL AGENTS

Understanding Pesticide Labels

The pesticide label gives the information necessary for each product's safe, effective and lawful use. **Remember, the label is the law.** Failure to read and follow the label directions is a violation that may result in fines or legal action against the pest control company and/or the applicator. It makes good sense to follow the label; by doing so, risk to the applicator, others and the environment is greatly reduced.

Supplemental label information is often attached to the product or available from the dealer to explain specific product requirements and geographic prohibitions (e.g. endangered species and additional county use restrictions). It is crucial to proficiently read and interpret pesticide label information.

Knowing how toxic a product is, and understanding the ways a person can be exposed to it, allows the applicator to lower the risk of exposure and damage to the environment. The toxicity of a pesticide cannot be changed, but understanding and following label directions, wearing proper personal protective equipment (PPE) and following all precautionary statements will greatly reduce the risk of misusing a pesticide.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was passed in 1972, and amended in 1974, 1978, 1988 and again in 2015. In 1996, the Food Quality Protection Act was signed into law. FIFRA regulates the registration, manufacturing, transportation, distribution and use of pesticides. The United States Environmental Protection Agency (EPA) administers FIFRA. Unlike most other types of product labels, pesticide labels are legally enforceable, and all of them carry the statement:

"It is a violation of federal law to use this product in a manner inconsistent with its labeling."

Exceptions to strictly following label instructions include only:

(A) applying a pesticide at any dosage, concentration or frequency less than that listed on the labeling;
(B) applying a pesticide against any target pest not on the label if the application is to a crop, animal, or site that is listed;
(C) use of any equipment or method of application that is not expressly prohibited by the labeling and
(D) mixing a pesticide or pesticides with a fertilizer, if the labeling does not prohibit the mixture.

Definitions

The State of Nevada defines a "pesticide" (NRS 555.267) as:

(1) "any substance or mixture of substances, including any living organisms or any product derived therefrom, or any fungicide, herbicide, insecticide, nematicide or rodenticide, intended to prevent, destroy, control, repel, attract or mitigate any insect, rodent, nematode, snail, slug, fungus and weed and any other form of plant or animal life or virus, except virus on or in living man or other animals, which is normally considered to be a pest or which the Director declares to be a pest."

(2) "any substance or mixture of substances intended to be used as a plant regulator, defoliant, or desiccant, and any other substances intended for that use as are named by the Director by regulation."

Label: the written, printed, or graphic matter on, or attached to, the pesticide, container, device or wrapper.

General Use Pesticide: a pesticide, when applied in accordance with its directions for use, warnings and cautions and for the uses for which it is registered, will not generally cause unreasonable adverse effects on the environment.

Restricted Use Pesticide: a pesticide, when applied in accordance with its directions for use, warnings and cautions and for the uses for which it is registered, may generally cause, without additional regulatory restrictions, unreasonable adverse effects on the environment, including injury to the applicator. Restricted use pesticide packaging and labels are clearly distinguishable from general use pesticides with a text box stating "Restricted Use" displayed prominently on the front panel.

Aerial: The use of aircraft for the application of pesticides on standing or running water, agricultural crops, rangeland, forest, idle cropland and noncropland associated with the production of agricultural crops.

Agricultural ground: The use of ground equipment for the application of pesticides on livestock, rangeland, agricultural crops, idle cropland and noncropland associated with the production of agricultural crops.

Categories of Licensing (Agricultural)
Aerial (A)

(1) Agriculture Plant Pests – the application of insecticides, miticides, acaricides, fungicides, bactericides and nematicides.
(2) Weeds – the application of herbicides, plant regulators, desiccant, and defoliants.

Agricultural ground (B)

(1) Agriculture Plant Pests – the application of insecticides, miticides, acaricides, fungicides, bactericides and nematicides.

(2) Weeds – the application of herbicides, plant regulators, desiccants and defoliants.
(3) Vertebrate pests—the application of various substances on agricultural ground for the control of vertebrate pests, including, without limitation, the use of fumigants for burrowing rodents. This category **does not** include the control of vertebrate pests in, on or around industrial complexes, institutional complexes, dwelling units or other structures designed for use by humans, or on ornamentals or turf in, on or around such structures.
(4) Soil fumigation – the use of various substances, including, without limitation, fumigants for the control of any pest that is present in the soil at the time of treatment, including, without limitation, plant-parasitic nematodes, soil borne pathogens, weeds and insects.

The Pesticide Label

The pesticide label is the information printed on the container, including any additional information included with the product. The label represents the best single source of information available to the applicator. The label is a legal document. **As such, "the label is the law."** Its importance to the buyer or user cannot be overstated. It is the source of facts on how the pesticide is to be legally handled and used.

Pesticide Properties

Information contained on the pesticide label is based on scientific research conducted to register the pesticide. Information on the pesticide's properties and its human health and environmental hazards must be submitted to the Environmental Protection Agency (EPA) for review and approval. If the pesticide is not approved, its registration application will be rejected.

Parts of the Label

Pesticide labels conform to a set of standards established by federal law. For the applicator, the label provides guidelines for correct application and pesticide usage. The label identifies the classification of the pesticide as either general or restricted use, and specific sites intended for application.

By law, **a pesticide can only be applied to a site identified on the label,** even though specific pests may or may not be listed. A site can be a crop, animal or location the product is applied or intended to protect.

The manufacturer is required to furnish certain information on the label, including
(1) brand name or trade name of the product,
(2) ingredient statement,
(3) percentage or amount of active ingredient(s) by weight,
(4) net contents of the container (type of formulation)
(5) name and address of the manufacturer.

Other required parts of the label are:

(A) EPA registration number and/or
(B) EPA establishment numbers,
(C) classification statement,
(D) directions for use,
(E) misuse statement,
(F) signal words and symbol,
(G) precautionary statements, including:
- Keep out of reach of children,
- Hazards to humans and domestic animals
- environmental hazard,
- pollinator protection, and
- physical and chemical hazards

(H) first aid,
(I) re-entry statements,
(J) storage and disposal statement,
(K) harvest or grazing restrictions as necessary.

The next section includes details on each part of the label.

(1) Brand, Trade or Product Name

A single pesticide active ingredient may be marketed at the same time under several trade names. Each label may designate a different use of the product. A specific brand name, usually registered as a trademark, will identify a product as produced by a particular manufacturer. Usually, the brand name shows up plainly on the front panel of the label and is the most identifiable name of the product.

Many pesticides have complex **chemical names.** Some have been given trade names to make them easier to identify. For instance, "Treflan" is a brand name for "Trifluralin" which is the **common name** for Benzenamine, 2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl). A pesticide made by more than one company will be sold under several brand names, but the same common name or chemical name should be on all of them.

(2) Ingredient Statement

Every pesticide label must list what is in the product. The ingredient information is written so that the product's **active ingredient** can be found quickly. Active ingredients are the chemicals in the pesticide product that actually control the pest. The amounts (percentage by weight or pounds per gallon) of the ingredients are also printed on the label. Often, the chemical name of the active ingredient is stated. If an approved common name of the active ingredient exists, it may be listed and may be followed by a chemical name (e.g. Trifluralin - Benzenamine, 2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)). Other ingredients called **other ingredients** are often added to products making them safer, easier to handle and apply. The name of the other

ingredient is usually not stated, but each label must indicate its percentage of the total product content.

(3) Net Weight or Measure of Contents

The net contents are displayed prominently on the front of the label. Net weight is often expressed as fluid ounces, pints, quarts or gallons for liquid formulations. Liquid formulations may also list pounds of active ingredient per volume (e.g. gallons) of product. If the formulation is a dry, semi-solid, viscous, pressurized, or a mixture of solids and liquids, the contents are expressed in ounces and/or pounds. Net contents may be expressed in metric units.

(4) Type of Formulation

The mixture of active and other ingredients is called a pesticide **formulation**. On some pesticide products the manufacturer will specifically identify the formulation of the product (e.g. HERBICIDE 5-G; the "G" stands for "granular"), while others will not. Where it is not clearly identified, it is sometimes possible to determine the formulation by reading the directions for use.

(5) Manufacturer

The name and address of the manufacturer, registrant or formulator who makes the product must be printed on the label. In some cases, this information will be found on the back panel of the label. If the registrant's name appears on the label and the registrant is not the manufacturer, it must be qualified by appropriate wording such as "packed for...," "distributed by..." or "sold by..."

(A) EPA Registration Number

An EPA registration number must be on every pesticide label showing the product has been registered with, and the label approved by, the U.S. EPA before being marketed. In most cases it will be written as in this example, "EPA Registration No. 1234-56." In cases of a "special local need registration," a pesticide product may be approved in a specific state for additional usage not specified on the label. As in this example, this type of registration number is designated as "EPA SLN No. NV1234" and means the product is registered for additional uses as a special local need pesticide in Nevada.

(B) EPA Establishment Number

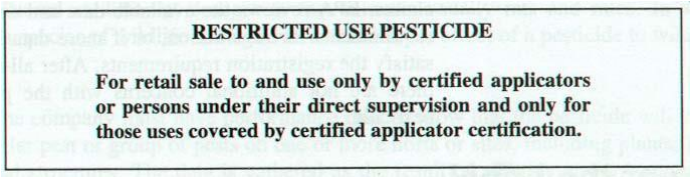
An establishment number identifies the specific facility that produced the product. The establishment number can be used to trace a pesticide to its manufacturing plant. The information is beneficial if problems occur with the product or if it has been tampered with or adulterated.

(C) Statement of Use Classification

Every pesticide is classified as either "General Use" or "Restricted Use." EPA places every pesticide product into one of these two classes. The classification is based on the hazard of poisoning and its effect on the environment. A pesticide classified as "General Use" won't

actually say "General Use" on the label. However, those classified as "Restricted Use" will be labeled as such on the top, center of the label.

- **General Use**: General use pesticides are less likely to harm the applicator or the environment when used according to label directions.
- **Restricted Use**: A restricted use pesticide is one that could cause some human injury or cause environmental damage even when used as directed on the label. The label of a restricted use pesticide will have a statement on the top of the front panel that reads: ***"Restricted use pesticide for retail sale to and use by certified applicators or persons under their direct supervision ....."*** In Nevada, "certification" is required for an applicator to purchase, apply or supervise the application of a restricted use pesticide. *(This manual is not intended to explain the process or necessity of restricted use pesticide certification. For more information, please contact a Nevada Department of Agriculture representative.)*


RESTRICTED USE PESTICIDE

For retail sale to and use only by certified applicators or persons under their direct supervision and only for those uses covered by certified applicator certification.

(D) Directions for Use

The instructions for applying a pesticide are considered as one of the most important parts of the label. Carefully reading and understanding the label are the best ways to find out how to correctly apply a product. Directions for use provide the following information:

- The pests controlled (labels use common names for pests; knowing these names will help when choosing the proper pesticide and in finding control information);
- The site (crop, animal, location, etc.) the product is intended to protect, or on which it can be used;
- Rates and methods of application;
- Times and/or frequency of application;
- Mixing directions;
- Any necessary application equipment; and
- Any pre-harvest interval (in days) may be listed. An applicator may deviate from the label directions **only in the following circumstances**:
    - Pesticides can be applied at less than the labeled rate (excluding pre-treatment applications for termite control);
    - Pesticides can be applied against any pest not listed on the label providing the crop, animal, or site is listed on the label (unless otherwise stated);
    - Any equipment or method of application that is not prohibited may be used (except chemigation);
    - A pesticide can be mixed with another pesticide (or fertilizer) if the mixture is not prohibited by the label.

(E) Misuse Statement

The misuse statement reminds the user that it is a violation of federal law to use a product in a manner inconsistent with its label directions. Do not use a pesticide on a crop, animal or other site not listed on the label. Do not use a pesticide at more than the recommended strength or rate of application.

Before a pesticide is registered with the EPA, the manufacturer is required to conduct many tests to insure the label directions are accurate. Following the directions exactly will give the best results.

Remember, the label is the law, and by not following the label directions users are breaking the law. Always read, understand and follow the label directions, it's the law!

(F) Signal Word and Symbol

To do their job, pesticides must control the target pest. By nature, pesticides are toxic and must be handled with extreme care. The toxicity of a product can be told by reading its **"signal word"** and looking at the **"symbol"** on its label. Each label will display a prominent signal word that indicates the relative toxicity of the active ingredient to humans. The hazard categories have been determined by considering the acute toxic effects of when a pesticide is swallowed, inhaled, or spilled on the skin. Effects on the eyes and external injury to the skin are also considered. The three signal words, in order of increasing toxicity, are **caution**, **warning** and **danger**. The signal word must appear on the front panel of each pesticide label.

Caution is the signal word required on the label of all pesticide products considered to be slightly toxic to relatively nontoxic when taken into the body orally, dermally or by inhalation; or that cause slight eye and skin irritation. A product with the signal word caution would require ingestion of an ounce or more to a pint to kill the average adult. A pesticide with a caution signal word can also be classified as a restricted use pesticide because of environmental concerns.
Warning is the signal word required on the label of all pesticide products considered moderately toxic when taken into the body orally, dermally, or by inhalation; or that cause moderate eye and skin irritation. A pesticide with the signal word warning would generally require ingestion of between one teaspoon (0.16 of an ounce) and one ounce to kill the average adult.
Danger/Poison, **Peligro** and the **skull-and-crossbones** symbol pictured to the right must appear on the labels of all pesticides that are highly toxic when taken into the body orally, dermally, or by inhalation. They may cause severe eye and skin irritation. A product with the signal word **danger** would require ingestion of as little as a drop to no more than one) teaspoon (0.16 of an ounce) to kill the average adult.

(G) Precautionary Statements

These statements guide the applicator in taking proper precautions to protect humans and animals that could be exposed to the pesticide. Some common precautionary statements include:

- **Keep Out of Reach of Children –** every pesticide label must include this statement on the front panel. This warning must be followed.
- **Hazards to Humans and Domestic Animals –** this label explains the ways in which the pesticide may be poisonous to humans and animals. It also tells of special precautions to take to avoid poisoning, such as protective clothing or other personal protective equipment (PPE). For example, the precautionary statements may direct the applicator to use rubber gloves, an approved respirator, and/or goggles when working with the pesticide.
- **Environmental Hazards –** pesticides are useful tools, but when applied incorrectly or carelessly, they can cause serious environmental harm. To help prevent this, the label contains environmental precautions that must be read and followed. For example, a label may contain one of the following statements:
    - *"This product is highly toxic to bees."*
    - *"Do not contaminate water when cleaning equipment or when disposing of wastes."*
    - *"Do not apply where runoff is likely to occur."*
- **Protection of Pollinators** – beginning in 2014, all pesticide labels of products that are potentially harmful to bees are required to have a bee advisory box and icon with information on routes of exposure and spray drift precautions. This box alerts users to separate restrictions that can prohibit use when bees are present.

- **Physical and Chemical Hazards** – tells the applicator of any special fire, explosion, or chemical hazards that the pesticide may pose. For example, a label may contain a statement like "*Keep away from heat or open flame*."

(H) First Aid

First aid treatment guidelines are recommended in this statement in case of over-exposure. These guidelines are very concise. This information should be read before the product is purchased or used, and again in case of emergency. For example, a statement may read "*In case of contact with skin, wash immediately with plenty of soap and water*." The label also contains a "note to physicians" describing the appropriate medical procedure for poisoning cases, and may indicate an antidote. The pesticide label is the most important information to take to the physician when someone has been exposed. Most labels list a phone number which can be used in the event of poisoning or other accident involving a product.

(I) Re-entry Statement

If required, some labels may contain a precaution to protect people after a pesticide application. This statement indicates how much time must pass before an area treated with a pesticide can safely be re-entered by persons not wearing protective clothing or equipment. If no re-entry statement appears on the label, no one must re-enter the treated area until any spray has dried or dusts have settled. That is the minimum legal re-entry interval.

(J) Storage and Disposal Directions

Upon purchase, the storage of the pesticide, the disposal of unused product and the disposal of empty containers is an important responsibility. This section of the label informs the applicator how to store and dispose of unused pesticides and dispose of empty containers. The storage and disposal section of a label may have instructions on how to dispose of pesticide rinsate and return the container for refilling (for sale or distribution), if it can be reused.

Typical statements may include:

- "*Store away from fertilizers, herbicides and fungicides.*"
- "*Store at temperatures above 32°F (0°C).*"
- "*Do not reuse container.*"
- *"Do not contaminate water, food, or feed by storage of disposal."*
- "*Triple rinse and offer this container for recycling or reconditioning, or dispose in an approved landfill or bury in a safe place.*"

These statements may appear in a special section of the label titled **Storage and Disposal**, or under headings such as "Important," "Note" or "General Instructions." Pesticide inventories should be stored securely, preferably under lock and key, and separated from food and feed products.

Summary of Pesticide Labels

The federal Environmental Protection Agency (EPA) administers the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA requires all pesticides produced in this country or imported, to be registered by the EPA and properly labeled.

The label is the basic legal document that controls the use of a pesticide. It is attached or printed on the pesticide container and must remain with the product throughout its life. All pesticide labels must be registered with the EPA, and all pesticides sold in Nevada must also be registered with the Nevada Department of Agriculture. All registered pesticide labels must have an EPA registration number and an establishment number. The establishment number tells which factory made the product. The establishment number may be on the label or on each container.

Labeling includes the label on the container and all brochures, flyers and other product information distributed with the product or by the pesticide dealer. Extensive scientific data is used to determine the efficacy, or killing potential, of a pesticide. Knowing the efficacy of a

pesticide is one of the prerequisites for registering a pesticide with the EPA. This data enables the pesticide producer to supply users with information about acute and chronic toxicity and possible hazards associated with the use of the product. Hazards may include possible injury to applicators or persons entering treated areas, unintended crop injury, injury to livestock, bees, fish, wildlife, etc.

The applicator **must have** the label, any supplemental labels (Nevada SLN registered pesticides), and any special use permits in their possession during the application to comply with state and federal laws.

READ, UNDERSTAND, AND FOLLOW ALL LABEL DIRECTIONS. IT'S THE LAW!

CHAPTER 2: WORKER PROTECTION STANDARD

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

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 enclosed space production facility (such as greenhouses or grow houses). The WPS requires the licensee 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 employees will be informed about exposure to pesticides, the WPS requires:

- Pesticide safety training for workers and pesticide handlers must be performed annually.
- A pesticide safety poster must be displayed for workers and pesticide handlers, including the nearest medical facility information.
- Access to pesticide labeling and safety data sheets (SDS) information for pesticide handlers and early-entry workers at the central location.
- Access to centrally-located information detailing pesticide applications that have occurred on the establishment.
- Mandatory posting of no-entry signs for outdoor production (e.g., farms, forests and nurseries) if the restricted-entry interval (REI) is greater than 48 hours.
- Licensed applicator information exchange: Custom applicators who apply pesticides for agricultural employers must share the pesticide application details. Agricultural employers are required to share this information with their employees.

Protection against exposures to pesticides

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

- 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 an 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. See: https://www.gpo.gov/fdsys/granule/CFR-2011-title40-vol24/CFR-2011-title40-vol24-sec170-224 to review the federal regulations and ensure compliance.

- Identify application exclusion zones (AEZ) up to 100 feet surrounding pesticide application equipment intended to protect workers and others from pesticide exposure during pesticide applications.
- Protect handlers during handling tasks, including monitoring while handling highly toxic pesticides and providing special instructions related to the correct use of PPE.
- Anyone under 18 years old are prohibited from being a pesticide handler or doing early-entry work during a restricted-entry interval (REI).
- If a respirator is required by the labeling, the employer must provide the handler with a medical evaluation, fit testing, and respirator training in compliance with the Occupational Safety and Health Administration's (OSHA's) Respiratory Protection Standard.

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. One gallon per worker, and three gallons per handler or early entry worker.
- If protective eyewear is required by the labeling, the employer must provide water for emergency eye flushing for handlers at pesticide mixing/loading sites.
- 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 must provide information about the pesticide(s) to which the person may have been exposed.

For more information on the WPS, consult the U.S. EPA web publication ""How to Comply with the Worker Protection Standard for Agricultural Pesticides: What Employers Need to Know**." at http://www.epa.gov/agriculture/htc.html.**

CHAPTER 3: PRINCIPLES AND APPROACHES OF 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. One of the primary reasons a pest control operator should be familiar with the characteristics and basic biology of common pests is to correctly determine the most effective method of control. As with any pest control, correct identification of the pest is the first step in an IPM program. Correct identification leads to knowing the pest's lifecycle and growth characteristics, that in turn assists with developing a pest management plan.

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 Cooperative 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 lady bird 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 other 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? What will happen if no action is taken? The action threshold in crop 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 damage by controlling the pest. The threshold is the pest density, or population level, at which a pesticide or other control method should be used.

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.

CHAPTER 4: SAMPLING PROCEDURES FOR PROPER PEST IDENTIFICATION AND TREATMENT

Procedures for Submitting Insect Samples for Identification

All samples submitted to the NDA must have a **completed** insect identification form **attached** to it. See http://agri.nv.gov/Plant/Entomology/Entomology_Home/. Upon clicking on the form link, the form will be downloaded to your computer where you can fill it out, print it and email it. Instructions on filling out the form can also be downloaded at the above link.

Samples may be hand-delivered to any NDA office or they may be mailed or shipped to:

Nevada Department of Agriculture
Attention: State Entomologist
405 S. 21st Street
Sparks NV 89431

Preservation of specimens

- Most specimens can be preserved in 70% ethanol (ethyl alcohol) whenever possible. Other forms of alcohol will work, but may affect the ability to identify the specimen.
- Never fill the vial more than halfway with specimens or materials.
- Host(crop) (what the specimens were collected on) should always be filled in on the form, if known.
- Always try to separate specimens from the host material and preserve before submitting.
- Always try to collect a minimum of 10 specimens – the more the better.
- Keep samples as cool as possible. Overheated samples from sitting on the dash or in hot vehicles are difficult or impossible to identify.

Special instructions

- **Aphids, Leafhoppers or Mite**s
  - Preserve in 70% ethyl alcohol.
  - Collect a minimum of 20, if possible.
  - Winged individuals should be collected, if present.
  - Do not ship on live plant material.
  - If damaged material is sent, send in a sealed plastic bag with material wrapped in dry paper towels, and label "Refrigerate on Arrival Notify Jeff Knight."
  - **HOST MUST BE FILLED IN ON THE FORM**.
- **Caterpillars, Maggots or Grubs**
  - Collect a Mminimum of 10 – the largest are best.
  - Before putting in 70% ethyl alcohol, fix in nearly boiling water. To do this bring water to boil, remove from heat and place larvae in water, small larvae (up to 1/2") only 5-15 seconds, medium (up to 1") 30-45 secs, larger 1-2 min. Try not to overcook the smaller larvae. Don't fix so many at once that the water cools too quickly. Remove, dry and place in ethyl alcohol.

Rules on Shipping

- All samples should have absorptive tissue (enough to absorb the alcohol in case of leaks or breakage) wrapped around the vial. wrap the submission form around it, then placed in a sealed plastic bag.
- Pack the shipping container with enough material to securely hold the vial in the mailing container.
- Less than 2 oz. of alcohol is usually sufficient for shipping.

Photographs for identification

Photographs may also be emailed to the state entomologist for identification. Remember to save the specimens, since many can't be positively identified from a photograph. Photos should be as close as possible to the specimen (macro mode, if your camera allows), yet still clear. Don't send blurry photos, as they cannot be identified. Be sure to include a completed identification request form with the photo.

Procedures for Submitting Plant Samples for Disease Diagnosis Sampling is a part of plant disease diagnosis. Incorrect samples often lead to an incorrect determination by a plant diagnostician or pathologist. When a plant shows symptoms, a thorough examination and preliminary investigation should be conducted in the field to determine which part or parts of the plant are affected and what type of sample should be taken for lab diagnosis. In some cases, this process may be complicated and may require additional information from the client.

For any samples taken, be sure to collect representative and problematic plant tissue and maintain the sample in an excellent condition. Samples that are rotted, dried, insufficient, or irrelevant to the problem are not useful for lab diagnosis. Always contact a local plant pathology professional for correct sampling instructions. Below are general guidelines for submitting samples to the NDA plant pathology lab.

Submitting samples to the NDA Plant Pathology Lab

(1) The NDA Plant Pathology Lab offers general diagnostic services to the community free of charge.
(2) Collect a sample from the affected plant on the day you intend to send it in or drop it off. Samples should be of problematic tissue. Check all parts of plants or trees and take representative samples from each affected part (leaf, fruit, stem, root, etc.)
(3) Place sample in a sealable plastic bag to prevent it from drying out. Do not place a moist paper towel in the bag, as the added moisture may cause bacterial growth that is not indicative of the actual problem affecting your plant.
(4) Keep sample cool (50-60°F) until it is submitted. Don't freeze it.

Completely and clearly fill out and attach it to the sample to be submitted. Forms may be downloaded online at: http://agri.nv.gov/Resources/Forms/Plant_Pathology_Forms/

(5) Provide additional information, such as disease photos, cultural maintenance history, spray history and any other information not reflected on the form, that may be useful in diagnosing your plant problem.
(6) Photos may also be emailed in assisting a diagnosis. Good photo submissions will include a clear, detailed image of the problematic area of the plant, in addition to an image of the entire plant. Email photos to shwang@agri.nv.gov andjschoener@agri.nv.gov.
(7) If you are mailing your plant sample, be sure to use a package/mailer that will prevent your sample from being crushed (i.e. cardboard box, bubble mailer).
(8) Hand-deliver plant samples to any NDA office, or mail to:

Nevada Department of Agriculture
Attn: Dr. Shouhua Wang
405 S. 21st Street, Sparks, NV 89431

Procedures for Submitting Plant Samples for Identification of Noxious Weeds

To properly identify weeds and potential noxious plants it is always best if samples contain flowers or fruits as part of the sample. If no flowers or fruits are available collect whole plants including roots. Samples may be taken to any NDA office or they may be mailed or shippedto:

Nevada Dept. of Agriculture
Attention: Sean Gephart
405 S. 21st Street
Sparks NV 89431

Photographs of plants can also be submitted for identification. A location photograph should be submitted along with a whole plant and macro image(s) of any distinguishing characteristics including flowers or fruits, if present, and individual leaf. Macro photos should be as close as possible to the specimen, yet still clear. Don't send blurry photos. Remember to save the specimens, since many can't be positively identified from a photograph. Photographs should be submitted to sgephart@agri.nv.gov.

CHAPTER 5: INSECTS AND ARACHNIDS

Insects and insecticides

In Nevada, more pesticides are applied to control insects and their relatives than to control any other pest. This is due primarily to the great number of these organisms: Two-thirds or more of all species of animals are insects, and they are exceeded in numbers only by microscopic animals.

Insects comprise the class Insecta. Other closely related animal classes include:

- Crustacea (Crayfish, pillbugs, sowbugs)
- Arachnida (Spiders, including tarantulas; ticks; mites; scorpions
- Diplopoda (Millipedes)
- Chilopoda (Centipedes)
- Collembola (Springtails)

All the above classes possess the following characteristics, which separate them from other animals:

(1) Jointed appendages (legs, claws, tails)
(2) Exoskeleton (composed partly of a chemical substance called chitin)
(3) Bilaterally symmetrical (one side is a mirror image of the other side)

Most of the agricultural pests in Nevada are insects (class Insecta), or mites and ticks (class Arachnida); these two classes will be discussed here. The other three classes are not major pests of agriculture in Nevada and will not be discussed.

Arachnida

Arachnid bodies are usually composed of two parts: cephalothorax (head and thorax) and abdomen. They have no antennae and simple eyes. Adults have four pairs of legs attached to the cephalothorax.

Spiders (including tarantulas) and scorpions are not agricultural pests in Nevada; normally they are beneficial as they prey upon insects and their relatives. Ticks can be economically detrimental, as they suck the blood of animals and transmit diseases. Mites attack plants and animals and have piercing, sucking mouth parts. When a mite attacks a plant, it punctures a leaf and sucks the plant juices; when it attacks an animal, it pierces the skin and sucks blood. Most mite and tick species deposit eggs which hatch into six-legged larvae. The larvae molt into eight-legged nymphs which in turn molt one or more times before becoming adults.

Insecta

In addition to the common characteristics found in all the above classes, adult insects have (however, the characteristics are not uniform for all insects):

- An exoskeleton which encases the insect and protects it against moisture, dryness, disease and natural enemies. It allows insects to live under a wide range of environmental conditions.
- A three-part body composed of head, thorax and abdomen.
- A head, which is unsegmented and bears the mouthparts, antennae and eyes.
    - Antennae are usually located between and in front of the eyes. Their function is sensory, particularly touch; in some instances, smell and hearing are located here. Some of the common types of antennae are: bristle- like, thread-like, saw-like, comb-like, club-shaped, and feather-like.
    - Adult insects have two types of eyes: simple eyes (ocelli) and compound eyes (faceted). When both types are present, there are usually two compound eyes and three simple eyes. A simple eye is usually quite small and has a single lens. A compound eye consists of numerous hexagonal figures known as facets.
    - Insect mouthparts differ according to how an insect feeds. Types of mouth parts include:
        (1) Chewing, which cuts, tears, chews and grinds the food. Example: grasshoppers.
        (2) Rasping-sucking, which rasp the surface of plants and suck the sap that exudes. Example: thrips.
        (3) Piercing-sucking, which punctures the skin of plants or animals and sucks up the sap or blood. Example: stink bug, mosquito.

(4) Sponging, which secrete saliva to soften the food, then sponges up the softened food. Example: house fly.
(5) Siphoning, which uses a long proboscis that dips into a liquid and siphons it up into the throat. Example: moths, butterflies.

- The thorax bears the insect's legs and wings.
- Insects generally have three pairs of legs attached to the thorax. Insect legs are modified for various purposes such as: jumping (grasshoppers), grasping (praying mantis), swimming (water boatman), and digging (mole crickets).
  The number of wings varies from two pairs to none. Insects are the only animals with wings other than birds and bats. The number of wings varies from two pairs to none. The most common group of insects having only one pair of wings are the flies (order Diptera).
- The abdomen usually consists of a series of 10 to 11 similar ring like segments. The last end segments may be specially modified. On female insects, on the end of the abdomen, is an ovipositor which is adapted for egg deposition. In wasp-like insects and bees, the ovipositor has been modified into a stinger. Along the lower margins of the abdomen are usually six to eight paired openings known as spiracles, which lead into the respiratory system.

Insects can multiply very rapidly. The rate of increase is governed mainly by the number of eggs laid, the length of a life cycle and the rapidity with which generations follow each other. Eggs hatch after a variable length of time. Insects that lay eggs are called oviparous; insects that retain eggs in the body of the female until hatched are called ovoviviparous. Insect eggs vary in size, shape, color, and markings. The number of eggs laid by an insect in its life varies, but probably average 100 to 200. Eggs may be laid singly in large batches at varying intervals or in small numbers over time.

When hatched, young insects may or may not resemble the adult into which it develops. The changes that occur in growth to an adult are called metamorphosis. Metamorphosis is usually divided into two types: complete and incomplete. Complete metamorphosis has four stages of development: egg, larvae, pupa and adult. Incomplete metamorphosis has three stages of development: egg, nymph and adult. For example, moths and butterflies undergo complete metamorphosis, and grasshoppers and Lygus bugs undergo incomplete metamorphosis.

Insect growth is highly dependent on temperature. Many insects require a period of cold temperatures to properly complete their life cycle. Depending upon the insect in need of control, there may be predictive models which can help determine when certain life stages or events are going to occur to optimize control efforts.

Some of Nevada's major crop pests

Unless otherwise noted, the most current threshold and chemical recommendations can be found online in the Pacific Northwest Insect Management Handbook.

ALFALFA LOOPER (*Autographa californica*)

Crops attacked: alfalfa hay, alfalfa seed

Description: Adult moths have silvery-gray forewings with an ivory colored, funnel shaped mark on the wings. The hind wings and the body are dull gray or brown. The wing span ranges from slightly less than one inch to slightly larger than one inch. They taper from rear to head and are approximately one inch long when mature. They travel in a looping fashion because the prolegs (fleshy hind legs on the abdomen) have been reduced to three pairs instead of the normal four pairs. Larvae are dark olive-green, with darker stripes down the sides, or black, interspaced with faint to distinct white lines.

Life cycle: The moth overwinters as a pupa either in the soil or in trash near the base of the host plant. Moths begin emerging in late April or early May, and females then lay eggs singly on the underside of leaves or on the stems of weed hosts. Eggs hatch in three to five days and the larvae feed for about two weeks before pupating in cocoons on the host plant or in trash. Adults emerge in about seven days and females deposit eggs about three days after emerging. The total development time from egg to egg is about 30 days. There are two to four generations each year, with populations peaking in May to late June.

Damage: Adults cause no damage, but small larvae feed on the leaves causing ragged holes. Larger larvae feed on the leaf margins and may defoliate a large portion of the plant.

Control: Chemicals are usually not necessary to directly control populations in alfalfa. Populations are often reduced by a virus and several predators and parasites.

ALFALFA WEEVIL (*Hypera postica*)

Crops attacked: alfalfa hay, alfalfa seed

Description: Adult weevils average from 1/4 to 3/10 inches long and have a short, defined turned-down snout. Color varies from light brown in young adults to a grayish brown or black in older adults. They have a broad, dark brown stripe extending from the front of the head along the middle of the back approximately two-thirds the length of the body tapering to a triangular shape on the wing covers. Weevil larvae are about 1/20-inch long when they hatch and are light yellow or yellowish-green with black heads. As they mature, they become darker green with a white stripe extending down the back. Full grown larvae are about 3/8-inch long. All larvae are legless, but have well developed ridges on the underside of the body which take the place of legs.

Life cycle: The alfalfa weevil overwinters as an adult in leaves, trash, weeds along ditch banks, haystacks or other protected places. Adults become active in early spring, mating takes place, and eggs are laid. The female initially lays eggs in dead hollow alfalfa stems and when the alfalfa reaches six inches tall, the females shift egg laying to growing stems. The adult female lays her eggs by chewing a hole in the stem before inserting the tip of her abdomen into the hole to lay a cluster of one to 40 eggs. The female lays from 600 to 800 eggs during her lifetime.

The eggs hatch in one to two weeks and the larvae feed in the interior of the stalk for three or four days then make their way to opening leaf buds at the tips of the plants where they feed concealed for a period. Once they are about half grown they feed almost entirely on open leaves, especially near the terminals. After four to six weeks, the larvae spin cocoons, and pupate in debris on the ground. Adults then emerge in 10 to 14 days.

Most adults leave the field soon after emerging and remain inactive during the summer, while some adults will feed on alfalfa throughout the summer. The old overwintering adults die by the time the first crop is harvested. In the early fall, the new adults go into hibernation. There is normally only one generation per year.

Damage: The plants attacked by larvae show a skeletonizing or shredding on the tips of the new growth. This injury increases from early spring until shortly before the time of the first cutting of alfalfa. In heavily infested fields the growing tips are eaten off, plant growth is stunted, and the leaves are skeletonized to such an extent that the field appears to be suffering from severe frost injury, presenting a gray or bleached-out appearance.

A field with a large adult population will usually be held back several weeks. Later when the adults feed on leaves, damage generally goes unrecognized. Rarely heavy populations can hold back the new growth after the first cutting. The alfalfa weevil is the most relevant pest of alfalfa hay in Nevada.

APHIDS

Crops attacked: There are numerous species of aphids that attack various crops, including:

- alfalfa hay alfalfa seed

- blue alfalfa aphid (*Acyrthosiphon kondoi*)
- pea aphid (*Acyrthosiphon pisum*)
- spotted alfalfa aphid (*Therioaphis maculata*)

Corn
corn leaf aphid (*Rhopalosiphum maidis*)

Mint
mint aphid (*Ovatus mentharius*)

Potato
green peach aphid (*Myzus persicae*)
potato aphid (*Macrosiphum euphorbiae*)

Small Grains
corn leaf aphid (*Rhopalosiphum maidis*)
no common name (*Rhopalosiphum padi*)
green bug (*Schizaphis graminum*)

Description: Aphids are soft-bodied "plant lice", about 1/16 inch to 1/8 inch in length. The largest is the pea aphid and the smallest is the spotted alfalfa aphid. Aphids can be green, yellow, brown, blue, black and yellow in color. They feed by thrusting sharp, hollow stylets from their beaks in among the plant cells and sucking out cell contents and sap. When feeding they may inject a toxic saliva into the plant. This may cause the plant to yellow and deform. Many feed only on certain plants while others feed on a wide variety. Winged and wingless forms may be present with the wingless nymphs being smaller versions of the adult.

Life cycle: The life cycle of aphids varies greatly with the species. Generally, aphids overwinter as eggs on plants and dead vegetation. The eggs are small, oval, blackish objects glued on their sides to the stems of plants. In spring, the nymphs hatch from the eggs, grow quickly to full size, but never get wings. These nymphs are females which reproduce young like themselves without mating. Their young are born ovoviviparously (i.e. already hatched from the egg) and differ from their mothers in having only one parent and in not passing through an exposed egg state. They are wingless and also produce young ovoviviparously, beginning when they are only a week or so old and producing from a dozen to 50 or 100 active nymphs within the following week or two. At some time during this period, either all or a portion of certain generations of these females may develop wings. They may fly to other plants of the same type or a different species known as the summer host. They settle down on the new host and start a succession of generations. In fall a generation of winged males and winged females is produced. The winged females return to the first host and give birth to wingless true females that cannot reproduce unless they mate with males of the preceding generation. The true female lays from one to four or more fertilized eggs in a sheltered place about the plant, and then dies. From these eggs next Spring's aphids which

differ from all the other generations of aphids by having both male and female parents. In some species the males and true females have no mouth parts.

Damage: Aphid feeding not only causes reduced plant growth but also blighting of buds, curling of leaves, and discolored spots on the foliage. When large numbers of aphids are present, plants gradually wilt, turn yellowish or brown, and die. Aphids secrete a sticky, sugary honeydew which gums up plants and harvesting equipment, and serves as a medium for growth of sooty mold fungus. Under severe infestations pea aphids can cause blossom drop on seed alfalfa. Both the spotted alfalfa aphid and blue alfalfa aphid inject toxic saliva when feeding on plants and thus fewer aphids are required to cause damage. Feeding by a single spotted alfalfa aphid can kill a very young plant. Blue alfalfa aphid toxin produces a marked stunting which may retard alfalfa regrowth as long as two weeks. Aphids are also important vectors of plant viruses.

Control: See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

ARMYWORMS (*Spodoptera* spp.)

Crops attacked: alfalfa, hay, alfalfa seed
western yellowstriped
armyworm (*Spodoptera praefica*)

Corn
fall armyworm (*Spodoptera frugiperda*)

Description: The adult moth has gray or brown forewings notched with slate or buff colored markings. The fall armyworm has a noticeable whitish spot near the extreme tip of the forewing. The hind wings of both are grayish white or silvery gray. The moths have a wingspan of about 1inches and measure approximately one inch from the head to the tip of the folded wings. Mature larvae are approximately 1to 2 inches long and vary in color from brownish gray to light tan, or green to nearly black. The western yellowstriped armyworm has a faint white or red mid-line stripe on the top of the body with black triangular marks on each side of the midline on each segment except on the prothorax. These black triangular marks are bordered below by a white stripe on each side. There is also a prominent black stripe along each side bordered below by an orange-brown stripe. The fall armyworm has three yellowish-white hair lines running down the back from head to tail; on the sides next to the yellow lines is a wider dark stripe and next to it an equally wide, somewhat wavy, yellow stripe, splotched with red. Both armyworms have a prominent white inverted Y on the front of the head.

Life cycle: These moths normally are killed during a cold winter but may overwinter in southern Nevada as half grown larvae if there is an extremely mild winter. Infestations normally occur from flights or wind-borne adults from more southern infestations. The female deposits eggs at

night on foliage in masses averaging 150 for the fall armyworm and 600 for the western yellowstriped armyworm; both deposit a total of about 1,000 eggs. The eggs hatch in three to four days. Small fall armyworm larvae feed near the ground gregariously at first, especially in the heart of the plant. Western yellowstriped armyworm larvae feed gregariously in the upper third of the plant. They do not hide in the soil during the daytime. When abundant, the larvae eat all the food at hand and then start to crawl in great armies into adjoining fields. These forced marches normally occur in the fall. Larvae feed on the foliage for six to eight weeks during May, June, and early July. The larvae then dig into the ground about one inch to pupate, within two weeks the adults emerge, fly some distance, and begin laying eggs within a week. The larvae that hatch from these eggs feed during late September and October.

Damage: The adult moths cause no damage. Larvae feed on plant foliage and tender stems. fall armyworm larvae feed on ears of corn in a manner identical with the corn earworm. Both larvae frequently feed on the terminal leaves and buds, and when aggregated on a few plants can cause complete defoliation.

Control: Larvae are most easily controlled when they are small and feeding on upper plant foliage. Insecticides should be applied when there are ten western yellowstriped armyworms per 180 degree sweep. For fall armyworms, treat when damage occurs. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

CORN EARWORM (*Heliothis zea*)

Crop Attacked: corn (corn earworm)

Description: This moth is named the bollworm, corn earworm, tobacco budworm, and tomato fruitworm. It has light grayish brown forewings, marked with dark gray irregular lines and a dark area near the wing tip. The irregular lines often shade into an olive-green. The hind wings are white with some dark spots or irregular dark markings. They have a wingspan of about 1inches. The larvae vary in color from a light green, pink, or yellow to brown or nearly black, and are lighter on the underparts. They are marked with alternating light and dark stripes running lengthwise on the body. The head is yellow and unspotted, and the legs are dark or nearly black. Mature larvae are about 1inch long.

Life cycle: The corn earworm overwinters as a pupa in the soil at the depth of two to six inches. Adults emerge in late May and June and begin laying eggs during the evening on suitable hosts. Each moth lays from 500 to 3,000 eggs, the average being probably over 1,000. Eggs hatch in from two to ten days, and the larvae feed for two to three weeks. When mature, larvae crawl down the stem or stalk, or drop to the ground, where they burrow and excavate a small smooth-walled cell, three to five inches deep, where they pupate. Adults emerge in two to three weeks and begin to lay eggs during the evening on suit- able hosts. There are two to three generations

each year with the first two generations occurring on corn or another suitable host. It is not until the third generation that the bollworm becomes destructive to cotton.

Damage: Corn Earworm eggs are laid singly on the leaves and in later generations on fresh corn silk. The larvae hatch and early generations feed in the curl of young corn plants. Later generations feed at first on the leaves or corn silk. They feed on the silk until it becomes dry and then on the kernels at the tip of the ear which are eaten down to the cob. Molds may be carried in through the husks resulting in diseased ears that may cause death among livestock to which they are fed. The presence of the worms in ears of sweet corn is most repulsive to consumers and very troublesome to commercial canners. The worms do not always remain in the first ear they enter but frequently go from one ear to another. They are cannibalistic and usually only one fully grown worm is found in each ear.

Control: See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

BROWN WHEAT MITE (*Petrobia latens*)

Crops attacked: alfalfa hay (minor pest), alfalfa seed (minor pest), garlic, onions, small grains, timothy

Description: Adults range in size from 1/100 to 1/50 inches long and have eight legs. When alarvae first hatches from the egg it has six legs. After molting it has eight legs through all nymphal stages. The color ranges from brown to red-brown for both the adults and nymphs.

Life cycle: The mite overwinters in the egg stage, hatching in the spring when vegetation appears and the weather is dry. After eight to eleven days, the nymphs reach adulthood and begin laying eggs. The eggs are deposited on soil particles or any solid object near the plants. Rising summer heat, with accompanying low relative humidity, cause females to lay glistening white heat-resistant eggs on ground litter, such as clods and sticks. Excessive moisture and flooding will kill these eggs and thus this mite thrives best in sandy soil areas. Adults have an average life period of two to three weeks.

The brown wheat mite has two "types" of females, the summer female and the winter female. Summer females lay 70 to 90 summer eggs within a three week period while winter females lay 30 winter eggs in the same time interval. In no case does any female lay both kinds of eggs. No males of this species have been found.

Damage: This mite is strictly a dry weather pest and its damage appears to be similar to that caused by drought. The mites withdraw plant sap for food and therefore heavily infested fields appear to be dried. Feeding by the mites causes a very fine mottling of the leaves and, at a

distance, a bronzing or yellowing effect may be seen. Injury to small grains may be evident as early as April.

Control: Irrigation will often decrease mite numbers so that treatment is generally unnecessary. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

CABBAGE LOOPER (*Trichoplusia ni*)

Crops attacked: garlic, onions, potatoes

Description: Adult moths are a general grayish-brown color, about one inch long with a wingspread of nearly 1inches. The front wings are sandy-brown with a small silvery or white spot near the middle resembling the figure 8. The inner loop of the mark is green and appears to be bowl shaped. The hind wings are paler brown to bronze. The larvae are an inch long when mature and are green to pale green in color. The body tapers to the head. There is a thin, conspicuous white line along each side of the body just above the spiracles and two others near the middle line of the back. The larvae have three pairs of slender true legs near the head and three pairs of thicker club- shaped prolegs behind the middle of the body. The middle of the body is with- out legs and is generally humped up when the insect rests or moves.

Life cycle: The cabbage looper overwinters as a pupa in the soil or in trash near the base of plants. Adults emerge in May and the female deposits eggs singly on the upper surface of leaves from late May to June. The moths are nocturnal, and the female lays from 275 to 350 eggs. The eggs hatch in about a week and larvae feed for two to four weeks before forming a pupal cocoon attached to leaves or in trash. Adults emerge within two weeks and the female begins laying eggs as before. The larvae usually cause the most damage in August. In the fall, these larvae pupate to overwinter.

Damage: All injury is by larvae which chew ragged-edged holes in leaves. In heavy infestations plants may be completely defoliated. If leaf tissue is severely damaged, plant growth is interfered with and edible portions stunted.

Control: Pheromone traps can be used to monitor emergence of males and can be used as an aid to determine the number of pests in the area. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

CUTWORMS

Crops attacked:
Alfalfa hay, alfalfa seed
army cutworm (*Euxoa auxiliaris*)
variegated cutworm (*Peridroma saucia*)

Garlic
army cutworm (*Euxoa auxiliaris*)
black cutworm (*Agrotis ipsilon*)

Onions
army cutworm (*Euxoa auxiliaris*)
black cutworm (*Agrotis ipsilon*)

Description: Adults are inconspicuous moths approximately one inch long from head to tip of folded wings. The body and wings are light dusty brown, grayish brown, or red brown. Army cutworm larvae are pale greenish gray to brown with the back pale-striped and finely splotched with white and brown, but without prominent marks. Variegated cutworm larvae generally are brownish gray, mottled, with a darker brownish dorsal (top) line and five or less brownish gray pyramidal marks on the rear dorsal sides. Below these marks is a more distinct brownish line extending along the sides. This line or narrow band may appear to be a series of connected "U's" as the larval body contracts. Black cutworm larvae are greasy gray or black with faint, lighter stripes. All mature larvae are less than two inches long.

Life cycle: Black and variegated cutworms overwinter in the pupal stage while the army cutworm overwinters as half-grown larvae. Black and variegated adults emerge in late May and

begin laying eggs: the variegated in clusters of 200 to 500 on the undersides of leaves or on stems of plants; the Black singly, or a few together, on the leaves or stems of plants often in low or overflowed land. Eggs hatch in four to seven days. Larvae feed on plant foliage for four to six weeks and then pupate in the soil. Adults emerge in late August and lay eggs which hatch into larvae, then pupate to overwinter. The black cutworm normally has two generations a year while the variegated has two to four irregular generations a year. The army cutworm emerges in spring and feeds on vegetation. When mature, they fall or migrate to the soil where they pupate. The adults emerge and often migrate to higher elevations for the summer. They return to the valleys in late summer and begin to lay eggs singly in or on the soil. The larvae hatch and, when half grown, return to the soil where they overwinter. The army cutworm has one generation a year.

Damage: The larvae of all three species cause crop injury. Black cutworm larvae eat plants just above, at, or a short distance below the surface of the soil and sometimes drag them to their burrows in the soil. Most of the plant is not consumed, merely being eaten enough to cause it to fall over. Variegated cutworms climb plant stems and eat the buds and leaves. Army cutworms occur in great numbers and after consuming nearly all the vegetation in an area; crawl along on the ground by the thousands to adjacent fields. They feed largely from the tops of the plants, without cutting them off, but when abundant will consume plants to the ground. They are most damaging in early spring.

Control: Cutworms are easier to control when small. Baits are effective, but when insecticides are applied the field should be irrigated before treating to bring cutworms to the soil surface. As cutworms are night feeders, applications should be made during late evening or at night. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

GRASSHOPPERS

There are approximately 113 species known in Nevada, however less than ten of these are known to cause enough damage to be considered pests.

Crops attacked: Nearly all cultivated and wild plants in Nevada.

Description: The nymphs or immature grasshoppers appear similar to adults except they are smaller and wingless. Adults vary from small to over two inches long. Their color varies from black, brown or gray mixed with yellow to green. Most adults are winged. The hind femur and tibia are greatly enlarged in comparison to the other legs.

Life cycle: Those grasshoppers of economic importance in Nevada overwinter as eggs in the soil. Nymphs emerge in April, May and June, and feed on vegetation for 40 to 60 days, undergoing five or six nymphal instars before molting into the adult stage. Adults then disperse to suitable hosts. In late summer adults mate and the females deposit eggs from late July through October.

The eggs are laid in packet-like masses below the soil surface. Each egg mass contains 20 to 120 elongate eggs, securely cemented together, the whole mass somewhat egg-shaped and dirt covered. A female may deposit from 8 to 25 egg masses. They are mainly deposited in uncultivated ground such as field margins, pasture land, and roadsides.

Damage: All nymphal stages and the adult stage do damage. Grasshoppers have chewing mouthparts and devour the leaves primarily. Large populations may devour the entire plant, including leaves, buds, flowers, and young seed pods.

Control: Insecticides applied to control other pests normally will control grasshoppers. If treatment is required, apply insecticides when damage is evident or when grasshoppers are moving into fields. On rangeland, treat when there are eight adults or more per square yard. ULV (Ulta Low Volume) applications are usually used on rangeland.

MORMON CRICKET (*Anabrus simplex*)

Crops attacked: Nearly all cultivated and wild plants in Nevada.

Description: Adults are about one inch long, pale yellow, green, black or dark brown and heavy bodied. The wings are very small and useless, except that the males use them to produce a mating chirp. The antennae are as long as the body, and the female has a sword-shaped ovipositor also as long as the body. The nymphs resemble the adults except they are smaller.

Life cycle: The winter is passed in the egg stage, 1/4 to 1 inch deep in usually barren, sandy soil in sunny locations. The eggs hatch in the first warm days of spring, February to April, usually a full month earlier than grasshoppers. The crickets pass through seven nymphal instars in about 75 to 100 days and become adults from early June to mid-July. The crickets mate and the females lay eggs all summer. The elongate eggs are deposited singly by thrusts of the long ovipositor with the female laying an average of about 100 eggs over a period of a week or more. The eggs are inserted into the ground with the female's ovipositor. The embryos become well developed before winter, but do not hatch until the following spring. The cricket rests at night and is active during the day. From the time they are about half-grown, they begin migrating from

their rangeland breeding grounds, moving from 1/8 to over 1 mile per day, going in no predictable direction, often in bands covering a square mile in area, and composed of as many as 100 to 500 individuals per square foot.

Damage: Mormon crickets have chewing mouthparts and prefer succulent vegetation but also eat sagebrush, other bushes, dung, and dead animals. They are also very cannibalistic. In large numbers they can completely defoliate vegetation.

Control: Populations of Mormon crickets should be reported to the Nevada Department of Agriculture or USDA-APHIS-PPQ.

LYGUS BUG (*Lygus elisus*, *Lygus hesperus*)

Crops attacked: alfalfa seed, other seed crops

Description: Adults are about 1/4 inch long by 1/8 inch broad, flattened, oval, and vary in color from pale green to light brown to dark reddish brown. There is a distinct, light colored triangle about 1/3 of the distance down the back just in front of the wings. When nymphs first hatch they are very pale green and have an orange spot in the middle of the abdomen. At this stage they are often mistaken for aphids, but are more active than aphids. Shortly after feeding begins the nymphs become a darker green. As they grow larger, the color varies from green to reddish brown to brown. The latter instars have four noticeable black spots on the thorax.

Life cycle: These insects overwinter as adults in trash in waste areas, field margins, and along road edges. Adults become active in spring and disperse into fields in late May and early June. Adults mate and females lay eggs in plant stems. Eggs hatch in one to three weeks as nymphs which feed on plant juices for two to three weeks before molting to the adult stage. New adults normally fly to new host plants, mate and begin laying eggs a few days later. There are normally three generations a year and occasionally four.

Damage: Adult and nymph lygus bugs are the most serious pest on alfalfa grown for seed. They have sucking mouth parts and physically damage the plant by puncturing the tissue and sucking the plant juices. There is also a toxic reaction from their saliva. Nymphal feeding is more destructive than that of the adults. Lygus bugs do their greatest damage by feeding on alfalfa buds. Injured buds turn tan to white, die, and drop from the plant within two to five days. Under severe conditions, nearly all the buds drop and the field assumes a grayish cast. Lygus feeding during blossoming also causes flowers to drop. The second most important type of damage occurs when lygus bugs feed on immature seeds. They puncture the pods and feed on the seeds causing the seeds to turn brown, later nearly black, shrivel and not germinate. Growth of the alfalfa plant can also be affected by lygus bug feeding. Stem length is reduced and stems become excessively branched with shortened internodes. Damage to cotton and sugar beet seed is similar to that described for alfalfa.

Control: See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

SAY'S STINK BUG (*Chlorochroa sayi*)

Crops attacked: alfalfa hay, alfalfa seed, cotton, small grains

Description: The adult stink bug is 3/5 inch long, bright green with minute white specks and three small white to pale orange spots at the base of the wing covering. The tip of the wing covering is more often white than orange, and with a narrow yellow or orange margin. Nymphs closely resemble adults except in size and lack of wings. Adults and nymphs have a disagreeable odor.

Life cycle: The say's stink bug overwinters as an adult near the ground surface beneath trash, around field margins, burned areas and road sides. Adults become active in early April and lay masses of "barrel shaped" eggs on the underside of leaves of various weed hosts. Nymphs feed on weeds or early planted crops. Adults migrate to cultivated crops where they lay eggs for another generation. There are one to three overlapping generations each season. Adults seek overwintering sites in October or before fall frosts.

Damage: Damage primarily results in shriveled seed after the bug extracts moisture from immature seeds. The bug can insert its long mouthparts into a pod and feed on the contents of the seeds. The seed is more completely collapsed than seed damaged by Lygus bugs, and feeding punctures are hard to detect on the outside of seed pods.

Control: This insect rarely causes enough damage to warrant treatments if they reach high populations treat when bugs first become active. Treat adjoining weed areas such as ditch banks as needed to reduce overwintering bugs. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

THRIPS - ONION THRIPS (*Thrips tabaci*)
WESTERN FLOWER THRIPS (*Franklinella occidentalis*)

Crops attacked: garlic, onions, timothy

Description: Adults range in color from pale yellow to straw colored to yellowish-brown to light brown and are about 1/25 inch long. Winged adults have two pairs of wings which are long and narrow with a fringe of long hairs on the margins. Males, especially of the onion thrips, are very scarce. The entire body is pointed at both ends nymphs resemble adults; except in size and lack of wings.

Life cycle: Adults overwinter in trash, under bark, in crop refuse or other protected places. Adults disperse to the fields in the spring and the females begin to lay eggs. The white bean-shaped eggs are thrust into the leaves or stems nearly full length and hatch in four to ten days. Nymphs begin to feed in flowers, buds, and leaves, for about five days. They then drop to the ground, burrow about two inches into the soil near the bulb and enter a pupa- like stage. Adults emerge in about four days. A generation is completed in 15 to 30 days. There are three to five generations each year. Hot, dry weather in July and August is favorable to rapid population increases.

Damage: Adults and nymphs rasp and puncture the leaf tissue surface and swallow the sap, together with bits of leaf tissue. This causes white or silver blotches on the leaves sometimes called white blast, white blight, or silver top. It also causes distorted leaves and buds. In heavily damaged fields, leaves become curled and twisted, growth stops and plants die back.

Control: See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

BROWN WHEAT MITE (Petrobia latens)

Crops attacked: alfalfa hay (minor pest), alfalfa seed (minor pest), garlic, onions, small grains.

Description: Adults range in size from 1/100 to 1/50 inches long and have eight legs. When a larvae first hatches from the egg it has six legs. After molting it has eight legs through all nymphal stages. The color ranges from brown to red-brown for both the adults and nymphs.

Life Cycle: The mite overwinters in the egg stage, hatching in the spring when vegetation appears and the weather is dry. After eight to eleven days, the nymphs reach adulthood and begin laying eggs. The eggs are deposited on soil particles or any solid object near the plants. Rising summer heat, with accompanying low relative humidity, cause females to lay glistening white heat-resistant eggs on ground litter, such as clods and sticks. Excessive moisture and flooding will kill these eggs and thus this mite thrives best in sandy soil areas. Adults have an average life period of two to three weeks.

The Brown Wheat Mite has two "types" of females, the Summer female and the Winter female. Summer females lay 70 to 90 eggs within a three-week period while winter Females lay 30 eggs in the same time interval. In no case does any female lay both kinds of eggs. No males of this species have been found.

Damage: This mite is strictly a dry weather pest and its damage appears to be similar to that caused by drought. The mites withdraw plant sap for food and therefore heavily infested fields appear to be dried. Feeding by the mites causes a very fine mottling of the leaves and, at a distance, a bronzing or yellowing effect may be seen. Injury to small grains may be evident as early as April.

Control: Irrigation will often decrease mite numbers so that treatment is generally unnecessary. See current threshold and chemical recommendations at: Insect Management Handbook https://pnwhandbooks.org/insect

SPIDER MITES (*Tetranychus* spp.)

Crops attacked: All cultivated plants

Description: Adults range in size from 1/100 to 1/60 inch long and have eight legs. The larvae resemble the adults but have only six legs. The color ranges from white to yellow to green to red. They usually have a pair of dark areas near the side of the body.

Life Cycle: Spider mites overwinter as pregnant females in protected locations such as loose bark and cracks in the soil. In spring females emerge, disperse, and for seven to ten days lay 50 to 60 eggs, usually on the underside of leaves. Eggs hatch into larvae in four to five days. Then nymphs become adults in ten to twelve days. A complete life cycle requires one to three weeks. In summer adults live one to two weeks, while during the winter they may live for over four months. There are usually seven or eight generations a year. Females cease feeding in the fall and migrate to overwintering sites.

Damage: The mites live on plant sap, which is drawn by piercing the leaf with two sharp slender lances attached to the mouth. Damaged leaves become blotched with pale yellow and reddish-brown spots ranging in size from small specks to large areas, on top and under surfaces. Leaves have a pale sickly appearance, gradually die, and drop. The mites gradually move upward, injuring and destroying leaves as they go. When conditions are favorable, they destroy most of the leaves, swarm to the tops, and spin great amounts of webbing. Mites are then blown on strands of webbing to new areas. Heavy mite infestations can kill plants. Dry, dusty fields are most likely to have problems with spider mites. Seasons that are unusually long, hot, and dry, (usually during late July and August), are ideal for mite development. Problems usually occur on hay in early spring.

Control: Treat alfalfa when 50 percent of leaves show damage or if the mites start to "web up" some of the flowers. Irrigation may help curb populations.

CHAPTER 6: PLANTS

Factors to consider when developing a weed management strategy for Agricultural Crops

SOIL
The characteristics of the soil where the crops are growing is an important factor to consider.

- Soil texture
- Soil pH

Soil texture refers to the relative amounts of sand, silt, and clay particles as well as the amount and quality of organic matter present. Soil particles contain cation exchange sites; the total amount is referred to as the cation exchange capacity (CEC). Soils with a high percentage of clay and/or organic matter have a much higher CEC than soils rich in silt or sand. Soil CEC is an important in gauging overall soil nutrient retention and also plays a role in herbicide retention and binding to soil particles. Many herbicide labels will indicate that it is necessary to use lower rates on sandy or silty soils and higher rates on soils rich in clay or organic matter. This is due to the fact that a high CEC soil will bind herbicide and thus make it unavailable for uptake by the target plants.

Soil pH can also have a significant impact on the effectiveness of certain herbicides. When herbicide labels have cautions involving soil pH they should be heeded. Finally, the grade or slope of an area needs to be considered. As slope increases, the potential of water runoff also increases which enhances the possibility of herbicides reaching non-target species and areas.

ENVIRONMENT
There are also a host of environmental factors that must be considered when developing weed control strategies.

- Light intensity and duration
- Temperature
- Soil moisture
- Humidity
- Precipitation
- Winds
- Solubility

Light intensity and duration are important in determining the growth, reproduction, and distribution of weeds. Shade tolerance is a major adaptation that enables many weed species to persist and thrive within a field of crops. The photo-decomposition of herbicides can also be greatly affected by light intensity and duration with higher intensities and longer duration accelerating the breakdown of many herbicides.

Temperature is also a major factor governing the rate at which plants germinate and grow, as well as absorb and translocate applied herbicides and growth regulators. Absorption by roots is decreased at lower temperatures while conversely, at high temperatures the volatilization of product is increased which may have adverse effects on nearby vegetation, animals, and humans.

Soil moisture is important in the uptake of soil applied products. Often recent precipitation or the use of irrigation is required for adequate uptake and effectiveness.

Humidity plays a major role in the effectiveness of uptake in foliar applied products. As a general rule, uptake and contact penetration is enhanced by higher humidity.

Precipitation (rainfall) soon after a treatment can decrease the effectiveness if product is washed off of the leaves. However, rain increases soil moisture, so soil applied treatments can be more readily absorbed by the target species. Hard rains may move product to outside of the target areas which is especially true in compacted soils or those with steep grades or slopes.

Winds (hot, dry) will decrease the effectiveness of foliar uptake and intensifies the risk of drift to non-target species. Target species with stiff, thick leaves are also prone to product displacement especially when high winds are present which will decrease the effectiveness of the application.

The water solubility of a soil applied product has a strong effect on how long a given treatment will persist and remain active in a given soil. The lower the solubility, the longer it will persist and the greater the amount of soil moisture necessary to solubilize and activate the chemical.

Plant Anatomy

All plants have the same basic body design of roots, stems, leaves, and reproductive structures (flowers or cones). Specializations of these structures may include underground stems for nutrient storage and asexual reproduction, and woody roots, stems, and branches in the case of shrubs and trees. The primary functions of roots are anchorage, and the absorption and transport of water and nutrients. Stems function as conduits of materials between the roots and the leaves or reproductive structures and as structural support. Leaves function in gas exchange to support photosynthesis and respiration. Leaf anatomy including the overall surface area, thickness, presence of and density of gas exchange pores (stomata) and presence of a waxy coating (cuticle) can have a major impact on the effectiveness of product reaching the interior of the plant.

The vast majority of crop plants and weeds fall into the category of flowering plants (Angiosperms). These plants, in turn, are divided into two major categories, the Monocots and the Dicots.

MONOCOTS

Monocots are grasses, sedges, palms, and bamboo. As their name implies they have a single seed leaf present in the ungerminated seed. Leaves typically are long and slender with parallel venation. Roots tend to be fibrous with many species having roots restricted to the top few inches of soil (although note that some of the more invasive species such as Johnson grass may have roots that penetrate much deeper into the soil profile). Flowers have parts in 3's or multiple of 3's or are inconspicuous.

DICOTS


Dicots have two leaves present in their seeds. The venation in leaves are netlike, and roots often have a deep central taproot. Dicots also exhibit a wide diversity of morphologies from strictly herbaceous (clover, dandelion) to bushes (creosote bush, roses) and trees (apple, maple) with true wood. Flowers have parts in 4's or 5's or multiples thereof.

Life cycle of common agricultural plant pests in Nevada

All plants exhibit a general life cycle of seed to juvenile to adult to reproductively active. The life cycles of various plants are divided into three general categories:

- Annuals
- Biennials
- Perennials

ANNUALS

Annuals complete their entire life cycle within a single growing season. These species can produce enormous amounts of seed in a single growing season. They are generally most troublesome in disturbed areas and soils that have been recently prepared for cultivation. Many species produce seeds that can lie dormant in the soil for many years before germinating and emerging when environmental conditions are favorable. They are easiest to control as young seedlings.

There are two "types" of annual plants, Summer annuals and Winter annuals. Summer annuals germinate in the spring, flower and produce seed in the summer and fall, and die before winter. Winter annuals germinate from seed in the late summer or fall and overwinter either as juveniles or young adults. They reproduce and die the following spring or early summer.

Puncture vine *(Tribulus terrestris*): Worldwide distribution. Thrives in arid and semi-arid environments. Both sun and shade tolerant. Usually forming flat patches, the stems radiate out from the crown and are hairy. Fruit is hard with spines robust enough to puncture tires and injure livestock. Seeds may remain viable for several years in the soil.

Purselane *(Portulaca oleracea*): Worldwide distribution. Thrives in poor, highly compacted soils. Highly drought tolerant. Succulent with taproots. Stems are reddish and mostly prostrate. Flowers can appear any time of year depending upon rainfall and temperatures.

Cheatgrass *(Bromus tectorum*): Widespread in Europe and North America. Thrives in semi-arid regions in a wide variety of soils but favors coarse textured soils with low salinity. Seeds germinate in fall and plants rapidly grow and flower in the spring. Seeds can persist up to 5 years in many soils. Extremely persistent in areas prone to frequent wildfire and will rapidly overtake and degrade such ecosystems.

Dodder (*Cuscuta spp.*): Widespread in tropical and temperate regions of the world. Yellow, orange, to red parasitic plants with many fine stems and minute scale-like leaves. Flowers in early summer and by late summer produce thousands of minute seeds. Can infest a multitude of plant species and spreads a variety of plant diseases.

Flixweed (*Descurainia sophia*): Widespread in temperate regions of the world. Part of the mustard family with characteristic erect, long stems with terminal small yellow or white flowerheads. Extremely fast growing and produce copious amounts of seed.

Lambsquarters *(Chenopodium album*): Worldwide distribution. Very fast growing and invasive broadleaf with inconspicuous flowers and fruits. Leaves have a variety of shapes, but upper ones have a whitish coat on underside and are waxy overall making them virtually unwettable. Especially favors nitrogen rich soils and wastelands.

Amaranth, Pigweed *(Amaranthus spp*.): Worldwide distribution. Mostly annual with a few perennial species. Temperate to semi-arid environments. Both flowers and foliage can be purple, red, green, to gold. Flowerheads are large spikes of many small flowers. Many species have extended periods of germination, rapid growth, and thousands of seeds per plant. Several species have developed resistance to conventional herbicides.

Filaree *(Erodium cicutarium*): Primarily North American distribution. May be biennial in southern regions of the USA. Sticky hairs on leaves. Bright pink flowers, fruits are shaped like a stork's bill that becomes curled and spiral when dry releasing seeds and later aiding to bury remaining attached seeds in the soil once fruit is detached from the parent plant. Often associated with harvester ants which feed upon the seeds.

Wild Oat *(Avena fatua*): Widespread throughout temperate regions of the world. Tolerates a wide range of soil types and pH conditions. Tufted grass with extensive deep roots. Stems are erect and hollow with many drooping seeds. Reduces soil quality through aggressive extraction of nitrogen and phosphorus. Seeds viable for over 5 years in soil.

BIENNIALS

Biennials live for two growing seasons. They germinate from seed in the spring or summer producing primarily foliage and storage excess nutrients in underground stems or fleshy taproots. They overwinter, some species with the above ground parts dying, with other species the vegetation survives. With both a cold period is usually required to induce flowering. The following spring or summer they regrow, produce seed, and die. They are easiest to control in the first year while in the juvenile vegetative phase.

Mustards, Yellow Rocket *(Brassica* and *Barbarea spp.*): Worldwide distribution. Temperate to semi-arid environments. Many common species native to USA and Europe but can become invasive in agricultural areas. May be perennial in some species. Rosette leaves long and highly toothed. Flower heads white or yellow clustered on tips of sparsely branching stems. Many seeds per season. Seeds may persist in soil for over 3 years. Deep taproots similar to Dandelion (*Taraxacum spp*).

Poison Hemlock *(Conium maculatum*): Worldwide distribution. Favors damp soils but can be found in drier areas that have been recently disturbed. Highly toxic to humans, moderately so to wildlife and domestic livestock. Plants devoid of hairs, stem hollow and often yellowish with

finely divided leaves and white flower heads resembling umbrellas. Emits a rank, unpleasant odor when crushed.

Scotch Thistle *(Onopordum acanthium*): Worldwide distribution. Thrives in areas with dry summers, sandy, sandy-clay, and lime soils and preferring areas of recent disturbance. First year is a rosette of spiny leaves. Second year a central stalk also spiny terminated by several bulbous purple inflorescences. Seeds are numerous and hairy, often spread by wind. Once established can spread rapidly into diverse neighboring habitats.

Hounds Tongue *(Cynoglossum officinale*): Primarily distributed in Central Europe and the Northern regions of the USA. Prefers wet soils, shaded areas and wasteland. Moderately drought tolerant. Forms a rosette of hairy leaves in year one. Black colored taproots may grow to 40" deep. Year two a central branching stem up to 4 feet tall develops. Flowers are red and purple. Seeds have small hooks that facilitate dispersal by animals. Toxic to livestock, releases an unpleasant odor when crushed.

Dyer's Woad (Isatis tinctoria): Primarily distributed in central Asia, Europe, and the Western USA. Well adapted to arid environments. Withstands freezing. Forms a rosette of blue-green leaves with long petioles in year one. Second year as many as 20 flower stalks develop with several bunches of yellow flowers. Degrades microbial populations in soil leading to decreased soil fertility thus is a major concern to rangelands and pastures.

PERENNIALS

Perennials live for more than 2 years and in some cases can live for hundreds and in rare cases thousands of years. Perennials can reproduce from seed and in many cases can also reproduce asexually through stems (both above and below ground) and specialized roots. Seeds will typically germinate in spring or early summer but first year plants normally do not flower during their first season of growth. Typically above ground parts go dormant over the winter and the survival of the plant depends upon a combination of temperature and moisture tolerance and the ability to store nutrients in underground structurers (roots, tubers, and rhizomes). Non-woody species resume growth each spring from leaf buds, roots, or underground stems. They flower and set seed in their second year and each year thereafter. Woody species may grow for several seasons before initiating flowering. Once they begin to flower, however, they will continue to flower for each year thereafter. Perennial species are often the most difficult to control or eradicate. Ideally, they should be treated in the first year. For mature plants systemic treatments (that work inside the plant as opposed to contact products) are often necessary.

Canada thistle *(Cirsium arvense*): Worldwide distribution. Thrives in disturbed areas such as post wildfire habitat and recently plowed fields. Herbaceous with extensive roots. Can propagate through roots and seed.

Leafy Spurge *(Euphorbia esula*): Widespread throughout the northern hemisphere as well as South America. Rapid growing herbaceous plant with yellowish umbrella-like flower clusters on tips of stems. Readily reproduces by seeds or roots with an extensive root system. The seed capsules open explosively distributing seeds up to 20 feet away from the parent plant. Seeds may remain viable in soil for over 5 years. All parts of the plant contain a milky, toxic white colored sap. Can rapidly replace native flora following an ecological disturbance.

Morning Glory, Bindweed *(Convolvulus arvensis*): Widely distributed in temperate regions. Rapidly growing vine that chokes out other plants where it is found. White to pink trumpet shaped flowers. Often found rooted in moist soil but can outcompete other species for sunlight, moisture and nutrients forming extensive mats. Seeds remain viable in soil up to 20 years.

Curly Dock *(Rumex crispus*): Widely distributed in temperate regions. Thrives in disturbed soils, waste areas, meadows, and along forest edges. Leaves form a large base rosette with flower stalks over 3 feet high. Flowers along stalk numerous and yellowish green. Seeds are sticky and will adhere to clothing or the fur of animals.

Russian Knapweed *(Rhaponticum repens*): Mostly Eurasia and North and Western USA. Persistent perennial with deep robust roots. Leaves form a rosette with central stems with terminal pink to purplish flower heads. Forms dense, bushy stands if not controlled early.

Whitetop *(Lepidium draba*): Primarily distributed in Asia, Europe, and the USA. Thrives in a wide variety of habitats and can withstand drought, freezing, and moderate salinity. Prefers alkaline soils but capable of invading any soil type. An aggressive colonizer of recently disturbed areas. Reproduces by both seed and roots. Extensive roots grow both downward and laterally. Leaves are long and thin, white flower clusters at ends of stems numerous, branching. Stems often woody at base of plant. Moderately toxic to humans and livestock. Carries several plant diseases of concern to agriculture as well as being a host for several agricultural insect pests.

Johnson Grass *(Sorghum halepense*): Worldwide distribution. Thrives in a wide variety of habitats and soil types. Cold and drought tolerant. Reproduces by roots, rhizomes, and seed. Leaves up to 3 feet long, strong robust central stalks up to 9 feet tall, roots and rhizomes grow up to 6 feet laterally. Can be toxic to livestock if consumed in quantity. Extremely invasive.

Weed identification and proper control measures

Aid in weed identification and picking the proper control measures can be found at the following link (Pacific Northwest Handbook) https://pnwhandbooks.org/weed

CHAPTER 7: FUNGI

Fungi are a distinct group of organisms that grow and feed on either living or dead organic material. Many species are benign but some can be serious pests of agricultural crops.

Anatomy

Some fungi such as yeasts are masses of unicellular organisms. However, most fungi, while often inconspicuous, are multicellular and exhibit a rather simple body plan. The basic vegetative structure is a thin strand of interconnected cells called a hypha. These structures release digestive enzymes that allow them to penetrate and absorb nutrients from organic matter (living and dead tissues of plants or animals). Hyphae are commonly found in masses that are termed mycelium.

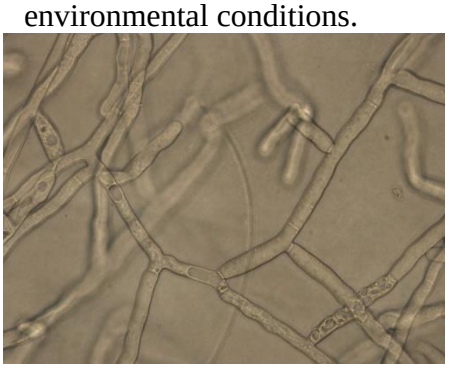
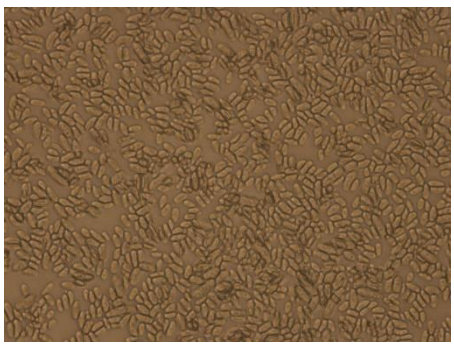
Life cycle

In many instances the predominant form of reproduction in fungi is accomplished asexually. As mycelium expand and hyphae penetrate into organic matter some of the exterior hyphae will differentiate into specialized structures (Conidia) that produce microscopic unicellular spores. These spores are capable of germinating into new hyphae which then can form new mycelium. When fungi reproduce sexually they will form hyphae into a mass known as a fruiting body (commonly referred to as a mushroom or toadstool) which will then in turn produce spores sexually.

Most fungal species live upon and decompose dead organic materials, but some species can cause diseases in plants. Fungi that only live on dead plant material are called saprophytes, and fungi that live on live plant tissue and cause diseases are called obligate plant pathogenic fungi. Some plant pathogenic fungi can infect live plants but also survive on dead tissue, and these fungi are called opportunistic plant pathogens. Typical symptoms of a fungal infection include necrosis or death of plant tissue, reduced growth, leaf spot, canker, blight, root rot, dieback, damping-off, and rot.

Morphology

The morphology of fungi is diverse and is used to describe many distinct fungal species. All fungi have living filaments that grow in a mass. The individual filament is called a hypha (Fig. 1, left), and the mass of hyphae is called mycelium. The fungal body spreads in all directions by the growth of the hyphal tips (Fig. 1, right). The size and shape of a fungal body is determined by the environmental conditions. Most fungi produce at least


two kinds of spores: sexual and asexual. The sexual spores are produced for survival during the winter or during adverse environmental conditions. The asexual spores are produced to aid in fungal dispersal. The shape and types of asexual spores vary greatly among fungal species. The most common asexual spore is conidium (Fig. 1, middle), which is often seen in infected plants during the growing season. Some fungi produce visible fruiting bodies, which are special structures containing an aggregation of hyphae and spores.

Fig. 1. Individual hyphae and mycelium of *Rhizoctonia* sp. (left), spores of *Fusarium* sp. (middle), and a colony of *Fusarium* sp. growing on a culture medium (right). (Photos by Shouhua Wang)

Life and Disease Cycles

There are about 300,000 species of fungi that have been described, and the number may be much larger because many fungal species have not yet been studied and identified. Among different fungal species, the life cycle can be quite different. The life cycles of plant pathogenic fungi are better characterized as disease cycles. In general, spores of a pathogenic fungus are dispersed to the surface of a plant and initiate infection when temperature and humidity are optimal. Spores germinate, penetrate plant tissue, grow mycelium intercellularly within the plant tissue, and kill a part or all of the plant. The fungus either survives in dead plant tissue or continues to produce asexual spores as secondary inoculum for further dispersal to new plants, killing a large number of plants during the growing season. After plants are killed, or at the end of season, some fungi produce sexual spores or fruiting bodies that can survive in soil, dead plants, or plant debris as the primary inoculum for the next year. The typical disease cycles are illustrated in Fig. 2. There are two types of disease cycles defined in plant diseases caused by fungi. One is called monocyclic, where a plant disease only goes through one infection cycle (Fig. 2, A). The other is called polycyclic, where a plant disease has many infection cycles during the growing season (Fig. 2, B). Most soil-borne plant diseases are monocyclic, and most air-borne plant diseases are polycyclic.

One important control strategy for monocyclic plant diseases is the elimination of the primary source of inoculum, such as fungal spores, sclerotia, mycelium, and other fungal structures. Soil fumigants and other fungicides used in soil treatment are good products to reduce primary inoculum. The control strategies for polycyclic plant diseases should be focused on eliminating the primary inoculum and controlling the secondary inoculum. Application of a fungicide during the growing season to control secondary inoculum greatly helps to protect a crop from being destroyed from repeated infections of fungal spores produced during the season.

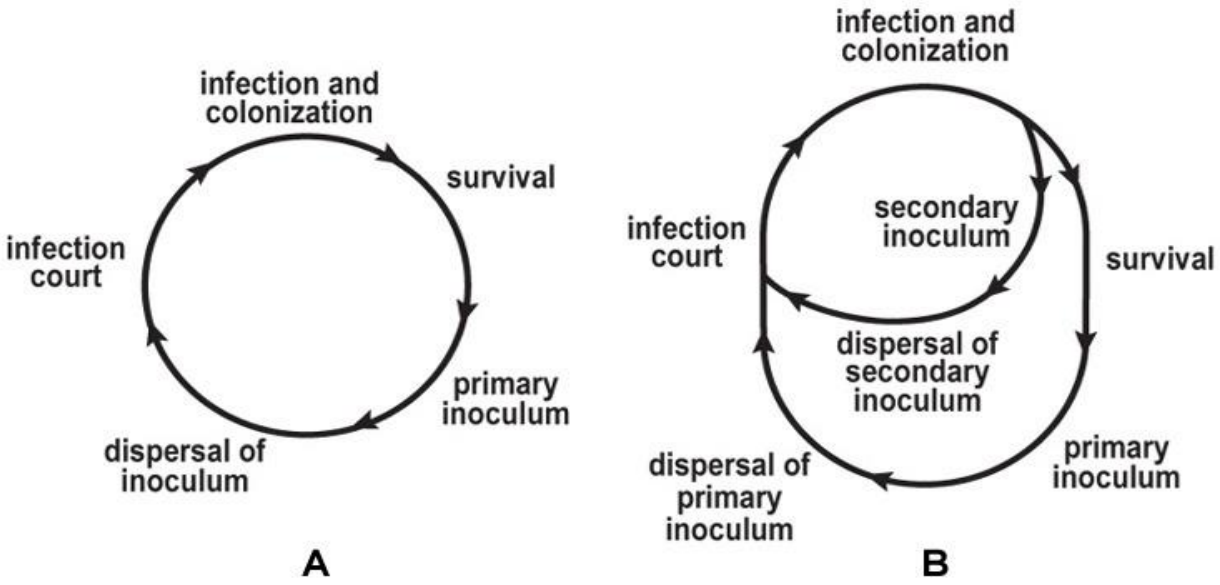


Fig. 2. Monocyclic disease (A) and polycyclic disease (B). (Illustration by courtesy of Richard Hoenisch, UC, Davis)

Plant Diseases Caused by Plant Pathogenic Fungi

Fungi cause many plant diseases, and almost all plants are subject to fungal infection. Any part of a plant can be infected by a fungal pathogen. Fungi cause many more plant diseases than other types of pathogens such as bacteria, nematodes, and viruses. The typical symptoms of infected plants include leaf spot, mildew, rust, smut, vascular wilt, dieback, damping off, stem canker, and root rot.

1. Diseases Caused by Fungal-like Oomycetes

A. *Phytophthora* Diseases

Phytophthora species used to be classified as a group of pathogenic fungi, but actually they are different from the true fungi. *Phytophthora* is a special group of pathogens that cause a large number of diseases on many plant species. They cause leaf spot, foliage dieback, bleeding canker (Fig. 3, left), stem canker (Fig. 3, middle), and crown and root rot (Fig. 3, right). Diseases caused by *Phytophthora* can be either air-borne, such as potato late blight, or soil-borne, such as many root rot diseases. Management of *Phytophthora* diseases requires integrated measures that include the use of healthy plant stock and resistant varieties, sanitation, crop rotation, and chemical treatment.

Fig. 3. Maple bleeding canker caused by *Phytophthora cactorum* (left), Azalea stem canker caused by *P. citricola* (middle) and Rosemary root rot caused by *P. nicotianae* (left). (Photos by Shouhua Wang)

B. Downy Mildew Diseases

Downy mildews are foliage diseases caused by a number of downy mildew fungi, which are also classified as fungal-like oomycetes. They affect various vegetable crops, grape, alfalfa, corn, wheat, grasses, sunflower, and other plants. The moldy growth of mycelium and spores predominantly occurs on the lower surface of the leaf (Fig. 4). Cool temperature and high humidity are favorable conditions for the disease development. Application of fungicides is effective in the prevention and control of downy mildew diseases.

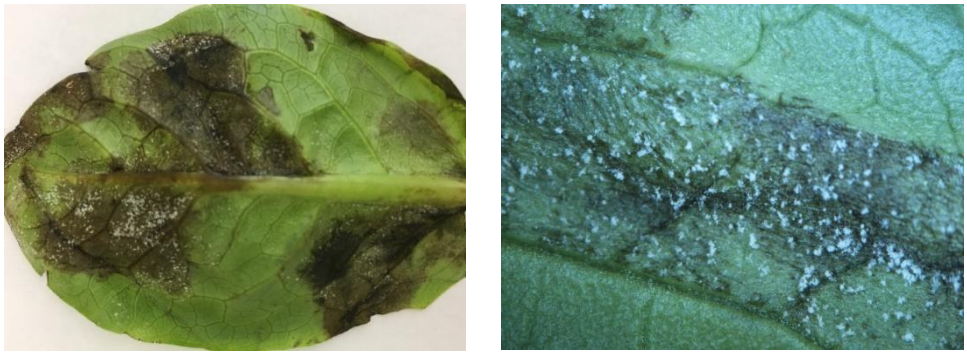


Fig. 4. Downy mildew disease on lettuce caused by *Bremia lactucae*. Note the moldy growth on the leaf (left) and magnified white mycelium (right). (Photos by Shouhua Wang)

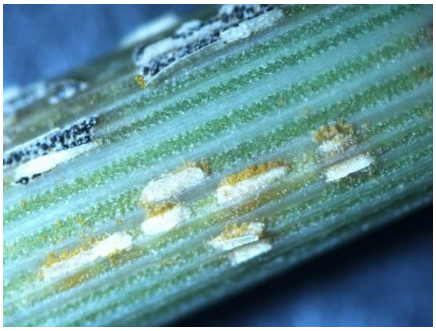
2. Diseases Caused by Ascomycetes and Imperfect (Asexual) Fungi

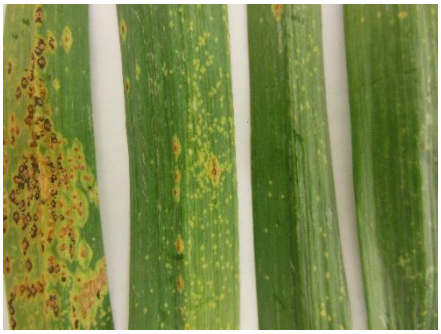
Ascomycetes and some asexual fungi (called imperfect fungi) cause the majority of known plant diseases. Ascomycetes produce both sexual spores called ascospores and asexual spores known as conidia. Imperfect fungi only produce asexual spores in natural conditions, or their sexual stages have not been found. Both groups of fungi cause the same kind of symptoms on plants, such as leaf spot, blight, canker, fruit spot, fruit rot, anthracnose, stem and root rot, vascular wilt, and soft rot. Common diseases we have observed in Nevada include sooty molds or canker, various powdery mildews, Alternaria leaf spot, needle blight of conifers, anthracnose of grasses, botrytis diseases, apple scab, *Fusarium* wilt, *Verticillium* wilt, Dutch elm disease, white rot of onions, and more. Depending on the causative fungal species, the disease development and epidemiology may be quite different in the field. Control of each specific disease caused by this group of fungi requires an accurate diagnosis and an understanding of the disease biology. Figure 5 shows some representative plant diseases caused by these two groups of fungi.

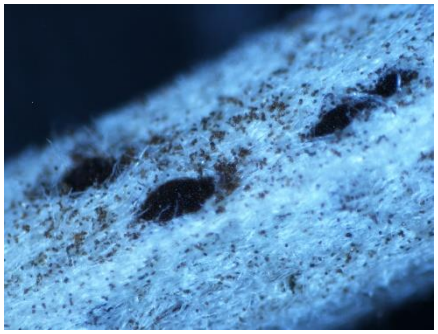
Fig. 5. Powdery mildew of euonymus caused by *Oidium euonymi-japonici* (upper left), vascular wilt of medical Marijuana plants caused by *Fusarium* oxysporium (Note the internal vascular discoloration) (upper middle), Alternaria leaf spot of cucumber caused by *Alternaria alternata* (upper right), *Botrytis* blight of tomato caused by *Botrytis cinerea* (Note the gray mold on the stem) (lower left), black scurf of potato caused by *Rhizoctonia solani* (lower middle), and white rot of onion caused by *Sclerotium cepivorum* (lower right). (Photos by Shouhua Wang)

3. Diseases Caused by Basidiomycetes

Basidiomycetes produce sexual spores called basidiospores. Most basidiomycetes are fleshy fungi that produce mushrooms and puffballs, which are either saprophytes or grow on the roots and trunk of trees causing wood decay. However, certain fungi in two orders of basidiomycetes cause rust and smut diseases in crops, ornamental plants, and trees. Common rust diseases include cereal rust, stem rust of wheat, cedar-apple rust, white pine blister rust, daylily rust, sagebrush rust, and more. Smut diseases include corn smut, kernel smuts of small grains, loose smut of cereals, and covered smut of wheat. Rusts and smuts are air-borne diseases that can be spread by strong winds, and their spores can be transported several hundred kilometers away. Seeds infected by rust and smut fungi can also carry diseases to new regions. The life cycle of rust fungi is complex, and some species require multiple host plants to complete their life cycle. Management of rust and smut diseases relies on the use of resistant varieties. When there is a disease outbreak in a field, systemic fungicides are often used to control the damage. In most cases, however, several applications are required during the season to achieve complete control. Figure 6 shows some representative rust and smut diseases caused by basidiomycetes.







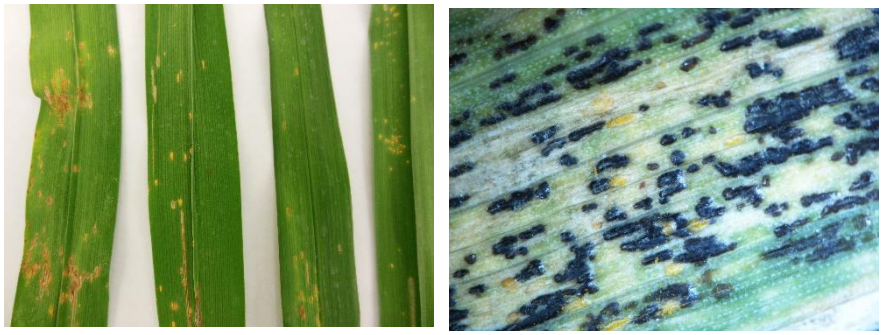


Fig. 6. Daylily rust caused by *Puccinia hemerocallidis* (upper left), wheat stripe rust caused by *P. striiformis* (upper middle), reed grass rust caused by *Puccinia* sp. (upper right), garlic rust caused by *P. allii* (lower left), sagebrush rust caused by *P. tanaceti* (lower middle), and wheat loose smut caused by *Ustilago tritici* (lower right). (Photos by Shouhua Wang)

CHAPTER 8: NEMATODES

Nematodes are microscopic, non-segmented roundworms. They are probably the most abundant multicellular animals on earth. The vast majority of nematodes are free-living in soil or in fresh or salt water without harm to plants or other organisms. A small number of nematode species can cause mild to significant damage to agriculture crops, horticulture plants, and forestry. These species possess a specialized feeding structure called a stylet. Most plant parasitic nematodes have a stylet and use it to penetrate plant cells and draw nutrients from the host plants. Plant parasitic nematodes can attack leaves, stem and roots, but the majority of them cause root damage. Many plant parasitic nematodes spend part of their lives freely in the soil, with the highest density around the roots of host plants. Plant parasitic nematodes may be spread by host plants, soil, field equipment, boots, or flood irrigation. Common symptoms of nematode infection include root galls, prolific root branching, root lesions, reduced plant growth and yield, yellowing, and wilting. It has been estimated that nematode damage to crops worldwide reaches $100 billion every year.

Morphology

The body of the plant parasitic nematode is a hollow tube extending from the mouth through the esophagus, intestine, rectum, and anus (Fig. 1). It is transparent and its internal organs are visible when observed under a light microscope. The body is covered by a colorless cuticle, and the body cavity is full of fluid. The nematode's cuticle is usually marked by striations or other markings, and molts when it goes through juvenile stages to become an adult. There are muscles in the nematode that enable it to move. The nematode has a complete digestive tract that includes the mouth, stylet, esophagus, intestine and anus. It has reproductive structures that contain testis and spicule (male) or ovary and vagina (female). Reproduction of the plant parasitic nematode is through eggs and may be sexual or parthenogenetic (males not required). Many species do not have males. Most nematodes are vermiform during their life cycles, but some species develop from vermiform juvenile stages into the round or lemon-shaped females (Fig. 2).

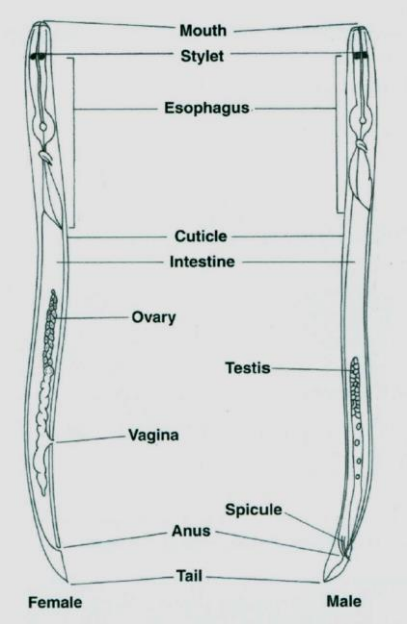


Fig. 1. The general anatomy of the plant parasitic nematode. (Adopted from Essential Plant Pathology by Gail L. Schumann & Cleora J. D'Arcy, 2006, APS)

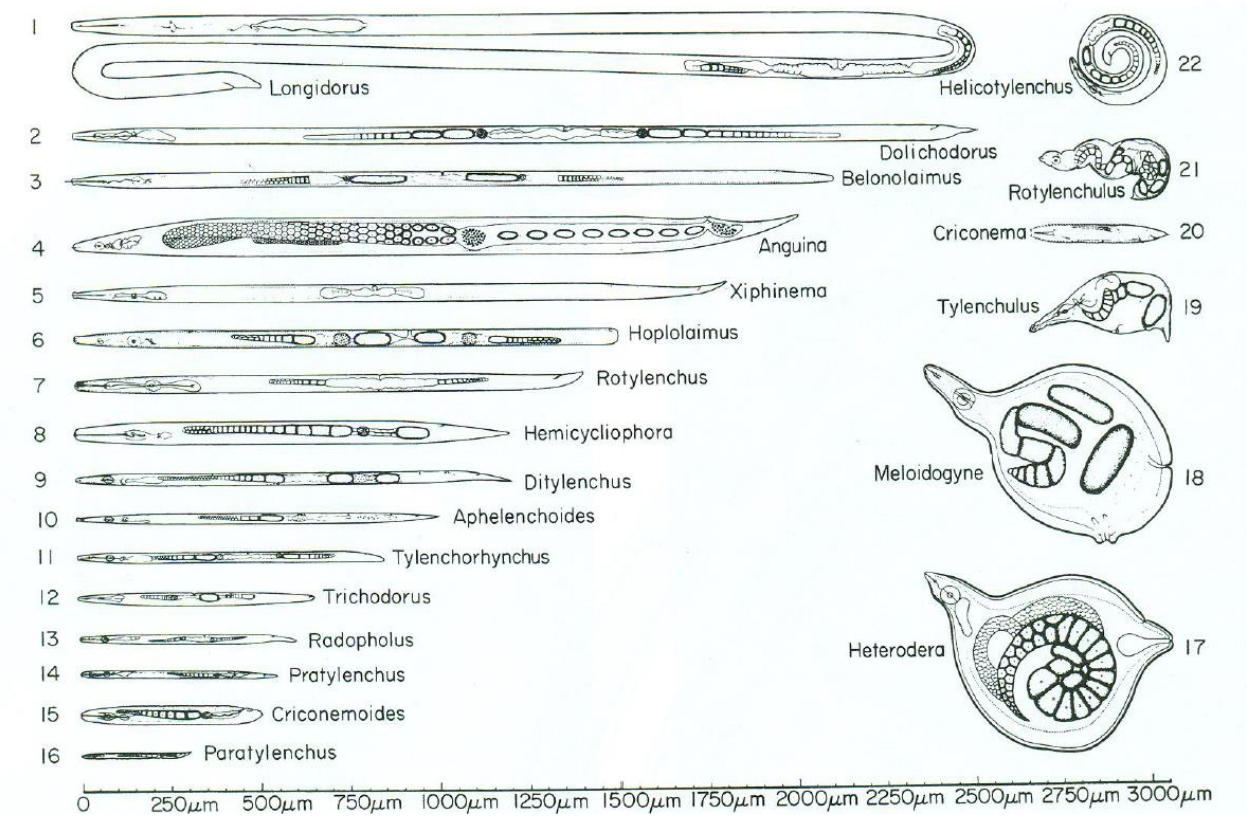


Fig. 2. Morphology and relative sizes of some of the most important plant parasitic nematodes. (Adopted from Plant Pathology by George N. Agrios, 1997, Academic Press).

Life Cycle

Most plant parasitic nematodes lay eggs, go through 4 juvenile stages, and become adult males or females (Fig. 3). Females lay eggs that can survive in the soil for a period of time with or without host plants. When a susceptible host plant is present and environment conditions (especially temperature) are optimal, eggs hatch into juveniles. Juveniles undergo four juvenile stages followed by a molt after each stage, and sex is established after the final molt. Depending on the species, females may produce eggs either sexually or asexually. In favorable environmental conditions, the nematode can complete its life cycle from egg to adult within a month. At the infectious stage (both juvenile stages and adults), plant parasitic nematodes must feed upon susceptible hosts in order to survive. Certain plant parasitic species may die if a suitable host plant is not available.

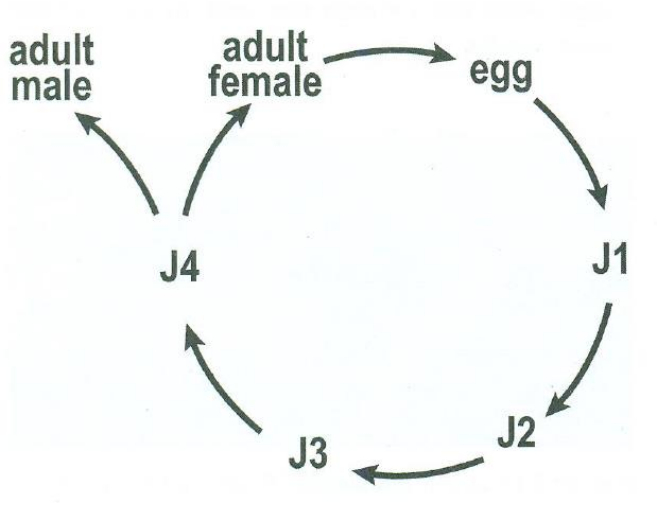


Fig. 3. A typical life cycle of the plant parasitic nematode with four juvenile stages (J1-J4). (Adopted from Essential Plant Pathology by Gail L. Schumann & Cleora J. D'Arcy, 2006, APS).

Plant Diseases Caused by Plant Parasitic Nematodes

Nematodes mainly infect roots causing mild to severe damage to plants. Some species infect leaves, stems or bulbs. The majority of plant parasitic nematode species live in soil and feed on root tips, and they are called migratory ectoparasites. Some species stay inside roots feeding on specialized plant cells, and they are called sedentary endoparasites. Some are migratory endoparasites that move through plant tissue while they feed inside (Fig. 5). Because nematode infection impairs the root system and nutrient uptake, affected plants show symptoms similar to those caused by nutrient deficiency. Common symptoms caused by the nematode include wilting, stunting, and yellowing.

The most economically important nematodes are:

- Root-knot nematodes (*Meloidogyne* spp.)
- Cyst nematodes (*Heterodera* spp., *Globodera* spp.)
- Lesion nematodes (*Pratylenchus* spp.)
- Stem and bulb nematodes (*Ditylenchus* spp.)
- Other species not found in Nevada

ROOT-KNOT NEMATODES

Root-knot nematodes (*Meloidogyne* spp.) infect a broad range of host plants. The disease they cause is one of the most common nematode problems in both agricultural and horticultural crops. The most characteristic symptom is the small to giant root knots or galls visible to the naked eye when the root system is pulled out from the soil (Fig. 4). Inside each knot, there may be one to several nematode females with an egg mass of at least 100 eggs. Root knot nematodes severely affect root function, so infected plants may show wilting symptom during the daytime due to insufficient uptake of water from the soil.

Root knot nematodes are difficult to control. Exclusion of the nematode from the crop production area is the best management practice. When the nematode is established in a field, nematicides are frequently used to reduce populations of the root knot nematode so that a crop can be successfully grown without significant impact on the crop yield.

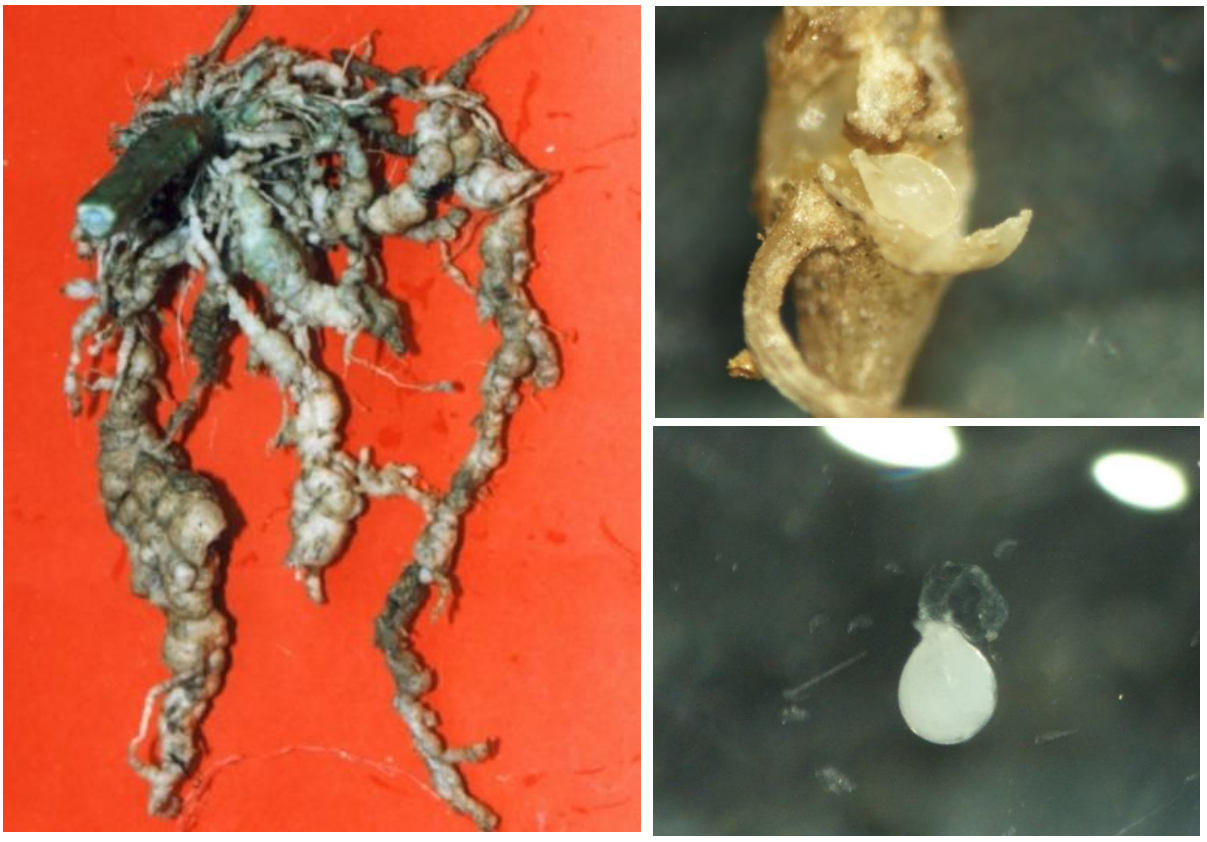


Fig. 4. Left: Root knots on a cucumber plant. Upper right: Root knot on a carrot root with a lemon-shaped nematode female removed from the root tissue. Lower right: A whitish female with a gelatinous sac. (Photos by Shouhua Wang)

LESION NEMATODES

Lesion nematodes (*Pratylenchus* spp.) are migratory endoparasites (Fig. 5). The nematode penetrates root tissue and move through the roots, which causes severe internal damage to the root tissue. The damage is often visible by dark lesions on the root. Roots infected by lesion nematodes are more prone to fungal or bacterial infections, causing complete destruction of a root system. The population of the lesion nematode can reach high levels in the field when a susceptible crop is planted, and thus causes significant damage to the crop. In general, lesion nematodes have wide host ranges, and crop rotation may have limited success in the management of lesion nematodes. Application of soil fumigants before planting or the use of

non-fumigant nematicides during the growing season can reduce the nematode population to a level below the economic damage threshold. When using nematicides, caution should be taken due to their high toxicity and environmental hazards.

Fig. 5. A female of the lesion nematode (*Pratylenchus* sp.) isolated from a potato field. (Photo by Shouhua Wang)

STEM AND BULB NEMATODES

The stem and bulb nematode (*Ditylenchus* spp.) occurs worldwide but is prevalent in the temperate zone. It is one of the most destructive plant parasitic nematodes. In Nevada, this nematode causes severe bulb rot on garlic and onion crops. A field infested with this nematode is no longer suitable for planting allium species. The initial symptoms on infected onion and garlic crops include erratic stands and collapsing of foliage. In the late stage of disease development, onion and garlic bulbs rot, desiccate, shrink, and become light weighted (Fig. 6). The severity of damage to bulbs depends on the density of nematodes in the soil. Highly infested crops are seldom harvested.

Early detection and eradiation of the nematode from garlic and onion production areas helps prevent nematode spread and maintains a nematode-free zone. When the nematode is established in a field, various nematicides and soil fumigants can be used in soil treatment to reduce the nematode population. Crop rotation with non-host crops has also been proved to be effective.

Fig. 6. Onion bulb infected with the stem and bulb nematode (*Ditylenchus dipsaci*) causing bulb rot in early stage (left) and desiccated at the late stage (right). (Photos by Shouhua Wang)

CHAPTER 9: BACTERIA

Bacteria are microscopic single-celled organisms that are found everywhere in the environment. Plants interact or are associated with many different types of bacteria. Some bacteria are beneficial to plant growth, some are neutral, but some are harmful and cause diseases in plants. There are thousands of bacterial species named in scientific literature, but only a small portion of bacterial species cause plant diseases under certain environmental conditions. Species of bacteria that cause plant diseases are called plant pathogenic bacteria or bacterial pathogens. The common symptoms of diseases caused by bacteria in plants include leaf spot, leaf scorch, soft rot, canker, blight, wilt, and death of plants.

The plant pathogenic bacteria can be classified into two major groups by the structure of the bacterial cell walls. One group of bacteria has thick cell walls, and the other has thin cell walls. When using gram stain, bacteria with thick cell walls are stained purple (called Gram-positive), and bacteria with thin walls are not stained (Gram-negative). There are about 30 bacterial genera, most of which are Gram-negative. Common Gram-negative plant pathogenic bacteria include *Agrobacterium*, *Erwinia*, *Pseudo*monas, and *Xanthomonas*. Common Gram-positive plant bacteria include *Clavibacter* and *Streptomyces*.

Another type of bacteria are called mollicutes and do not have cell walls. These include phytoplasmas and spiroplasmas, both of which can cause diseases in plants. Both phytoplasmas and spiroplasmas only live in live plant tissue, so they are obligate parasites.

Mycoplasmas consist of cytoplasm, nuclear material, and ribosomes (protein synthesizing subunits). Because they lack a cell wall, they range in shape from ovoid, to spherical, and to filamentous. Mycoplasmas reproduce by budding and binary fission, where genetic material is duplicated and splits into two.

Phytoplasmas are round, ovoid, or elongate in structure and consist of cytoplasm, nuclear material, and ribosomes. Phytoplasmas cause apple proliferation, citrus stubborn disease, pear decline, peach X-disease, aster yellow, ash yellow and decline, and many other destructive plant diseases. Main symptoms of phytoplasma infection include stunting, uniform discoloration of leaves (yellow or red), abnormally small leaves, shoot proliferation, the loss of pigment in flowers, shortening of internodes, reduced yield, and rapid dieback.

Morphology

The majority of plant pathogenic bacteria are bacilliform (Fig.1, left), with some strains being more elongate or filamentous, or even slightly club-shaped. Many bacteria have thin, whip-like protrusions called flagella, some species have only one flagellum, and other species have flagella across the entire surface. Mollicutes such as phytoplasma and spiroplasmas have variable shapes. Plant pathogenic bacteria are 1-3 micrometers in size and are only visible under a microscope. When the bacterium is grown on a culture medium, hundreds to thousands of bacterial cells can form a colony visible to the naked eye (Fig.1 right).

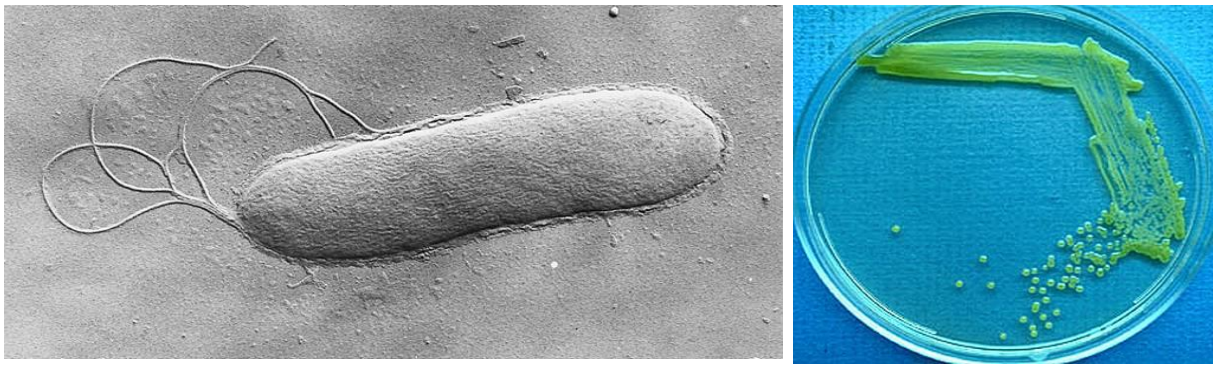


Fig.1 Left: A bacilliform bacterium, typical of plant pathogens. Note that it has polar flagella. Right: Bacterial colonies on a nutrient medium. Note that each small, round colony consists of hundreds of cells grown from a single cell. (Adopted from Essential Plant Pathology by Gail L. Schumann & Cleora J. D'Arcy, 2006, APS, and color picture courtesy of R. Hoenisch, UC Davis)

Life and Disease Cycles

Plant pathogenic bacteria reproduce and develop within the host plant, on the surface of the plant, on plant debris, or in the soil. The rod-shaped bacteria reproduce through binary fission, in which one bacterium splits into two, those two bacteria become four, and so on. Binary fission occurs when the cytoplasmic membrane grows inward towards the center of the cell, forming a membranous partition and dividing the cytoplasm in half. When the formation of the cell walls between the two is complete, the two cells split apart. While the rate of reproduction depends on the environmental conditions, bacteria are capable of reaching exponential numbers in a brief period of time.

Most plant-pathogenic bacteria are facultative parasites, which means that the bacteria can survive without association with a host plant. Therefore, they can be easily cultured on a standard nutrient media. Some bacteria are only associated with live plant tissue and cannot be cultured on a nutrient medium unless a specialized medium is developed. This type of bacteria is called fastidious bacteria. Some fastidious plant-pathogenic bacteria are xylem-limited, such as *Xylella fastidiosa* causing bacterial leaf scorch and Pierce's disease of grapevine. Some are phloem-limited, like Phytoplasmas, which cause over 300 known plant diseases.

Most plant pathogenic bacteria do not produce special structures for survival in adverse conditions. They can survive on leaves, flowers, fruits, stem, and roots for a short period of time as epiphytes. Some can survive in soils as soil inhabitants or saprophytes. These types of bacteria can infect new plants or crops whenever they are in contact with a host plant surface under favorable environmental conditions. Fastidious bacteria live inside the xylem or phloem tissue of plants as obligate parasites and can be transmitted to other plants by insects such as sharpshooters and leafhoppers.

Plant Diseases Caused by Plant Pathogenic Bacteria

Under favorable environmental conditions, plant pathogenic bacteria can infect plants, causing various types of symptoms such as leaf spot, yellowing, chlorosis, canker, gall, rot, and vascular wilt. The initial symptom might be water-soaked lesions on the plant tissue due to the enzymatic digestion of the plant cells by the bacteria. Depending on the plant tissue affected and the type of plant pathogenic bacteria involved, the symptoms of infected plants vary significantly. The following are examples of common bacterial diseases.

1. CROWN GALL

Crown gall is a very common bacterial disease. It is caused by the bacterium, *Agrobacterium tumefaciens*. The disease affects woody and herbaceous plants in about 140 genera of more than 60 families. The initial symptom appears as a small, round, whitish, and soft overgrowth or tumor on the stem and roots near the soil line. The plant tumor may continue to grow into a very large size with the outer tissue becoming dark brown. Crown galls are generally irregularly shaped and usually surround the stem or root. Crown gall disease is mostly found on pome and stone fruits trees and grapes. Control of crown gall requires early detection and prevention. Inspection of nursery stock and destroying infected plants are crucial to prevent the spread of the bacterium to new sites. Biological control of crown gall has been practiced for years by soaking germinated seeds or dipping rootstocks in a suspension of a biocontrol agent such as No. 84 strain of *Agrobacterium radiobacter*. Chemical control of crown gall is very limited.

Fig. 2. Giant gall on oak tree caused by *Agrobacterium tumefaciens* (left) and crown gall on a grapevine caused by *A. vitis* (right). (Photos by Shouhua Wang)

2. FIRE BLIGHT OF PEAR AND APPLE

Fire blight is a destructive disease of pear and apple. Some varieties are very susceptible to this disease. The pathogen, *Erwinia amylovora*, is a rod-shaped bacterium with peritrichous flagella (a tail-like projection all over its surface). This bacterium can also infect many ornamental species. Fire blight is contagious and causes “fire-scorched” symptom on leaves, fruits, twigs,

and branches (Fig. 3). In the active disease developing stage, water-soaked lesions or bacterial ooze appear on affected branches. Cool and humid conditions favor the disease development. Control of fire blight requires integrated disease management practices. These include 1) all blighted twigs, branches, and cankers should be cut at about 5 inches below the visible infection point and burned, 2) chemical control with appropriate bactericides to protect trees from new infection, and 3) remove and destroy severely infected or dead trees from the field or site.

Fig. 3. Fire blight of apple (left) and pear (right) caused by the plant pathogenic bacterium, *Erwinia amylovora*. (Photos by Shouhua Wang)

CHAPTER 10: VIRUSES, VIROIDS, AND MYCOPLASMAS

Viruses are infectious, intracellular pathogens that are submicroscopic particles composed of protein and nucleic acid. They are obligate parasites living inside plant cells. Viruses infect plants and hijack the host's nucleic acid replication system to reproduce their own particles. Because of this, the normal physiology of the plant is affected, thus resulting in a wide range of symptoms, including mosaic, stunting or dwarfing, yellowing, ringspot, leaf roll, deformation, and even death of plants. Symptoms caused by viruses are generally systemic, and they can be seen on any part of plants, but mostly on leaves. Symptoms caused by viruses can be confused with herbicide damage or other abiotic factors, therefore, a test is often needed to confirm a virus infection. Many plant species are susceptible to virus infection, and infected plants are often not treatable to reverse the infection.

Morphology

Individual virus particles, also called virons, are extremely small and not visible under a standard light microscope. The size of virus particles is measured in nanometers, and they have to be magnified over 10,000 times to be visible to the naked eye under an electron microscope. A typical plant virus particle is rod shaped or spherical (Fig. 1 and 2). The smallest spherical viruses are 20nm or less in diameter. The rod-shaped tobacco mosaic virus (Fig. 2) is 300 x 15nm in size. Some plant viruses are bacilliform or filamentous (Fig. 1).

Most plant viruses have only two types of macromolecules: the nucleic acid and one or more proteins. The protein forms a coat that encloses the nucleic acid. The nucleic acid is either ribonucleic acid (RNA) or deoxyribonucleic acid (DNA). Most plant viruses have single stranded RNA (ssRNA). Some have double-stranded DNA (dsDNA) or double-stranded RNA (dsRNA).

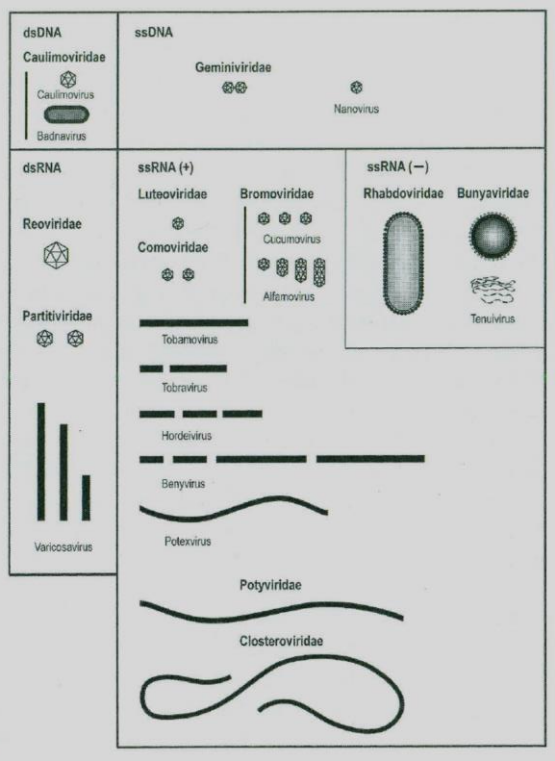


Fig. 1. The variety of shapes of virus particles and the types of nucleic acid genomes in some of the families and genera of plant viruses. (Adopted from Essential Plant Pathology by Gail L. Schumann & Cleora J. D'Arcy, 2006, APS)

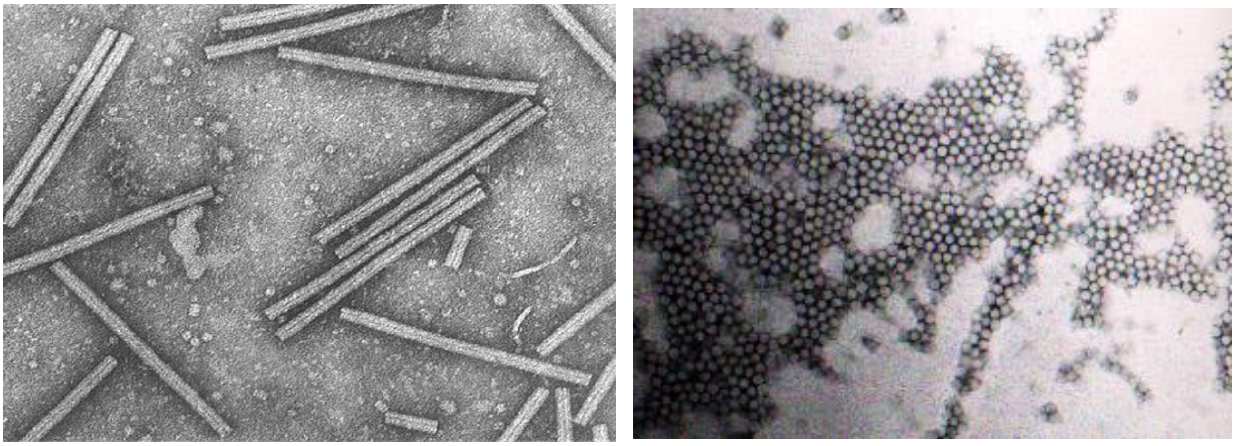


Fig. 2. Rod-shaped particles (300 x 15 nm) of tobacco mosaic virus (TMV) (left) and spherical particles of a plant virus (right). (Photo of TMV adopted from Essential Plant Pathology by Gail L. Schumann & Cleora J. D'Arcy, 2006, APS. Photo of the spherical virus by Shouhua Wang)

A viroid is one of the simplest organisms and is the smallest infectious pathogen known. Unlike the virus, a viroid is simply an infectious, short, circular, single stranded RNA molecule without a coat protein. The first recognized and mostly studied viroid is the potato spindle tuber viroid

(PSTVd). PSTVd is an important plant pathogen that poses a threat to potato production worldwide. Potato plants infected by PSTVd exhibit symptoms of stunting, small and twisted leaves, and small and spindle-shaped tubers. PSTVd is transmitted by contact. Mechanical injury and some insect feeding activities also cause the spread of the viroid in a field. The viroid is also transmissible by infected seed potato tubers and true potato seed. Management of potato spindle tuber viroid relies on cultural practices to exclude infected seed stock from planting. Certification of seed potatoes by periodically monitoring and testing for PSTVd is an essential program for providing high-quality and viroid-free seed potatoes

Life and Disease Cycles

Plant viruses complete their life cycles inside the cell of a host plant. Viruses use the plant cell's replication system to replicate its RNA or DNA and synthesize the coat protein. Replicated new RNA or DNA and newly synthesized coat protein are assembled together to form a virus particle. In each host plant cell, hundreds to millions of virus particles can be produced. Some plant viruses are easily transmitted by contact, but many are transmitted by insects and mites, including aphids, whiteflies, leafhoppers, thrips, and eriophyid mites. Some viruses are transmitted by migratory ectoparasitic nematodes, such as dagger nematodes (*Xiphinema* spp.), needle nematodes (*Longidorus* spp.), and stubby-root nematode (*Trichodorus* spp.). A few soilborne fungi and fungus-like organisms also transmit certain plant viruses. Transmission of plant viruses to the next generation of plants can be accomplished in several ways. Infected seed can carry viruses to the next crop directly. Vegetative propagation of infected stock plants effectively passes viruses to the next generation. Over-seasoning insect vectors deliver viruses to the next-year crop plants. Some infected weeds and virus-carrying nematodes may also serve as sources of infection for next crops.

Plant Diseases Caused by Plant Pathogenic Viruses

Viruses attack all types of plants, from herbaceous to trees. They can damage any or all parts of a plant. Some viruses can cause catastrophic loss in yield and quality of a crop. The most visible symptoms caused by plant viruses are leaf mosaic, deformation, stunting, and poor growth. Symptoms caused by different viruses may look similar. One plant can be infected by two or more viruses. Confirmation of a virus infection requires serological tests. Most viruses can be detected in a laboratory using either immunostrip or DAS-ELISA testing. Control of plant viruses requires a system of quarantine, inspection, and certification, which is the best way to exclude viruses from a crop. When a destructive virus is detected, eradication is necessary and often achievable. Roguing has been successfully used to eliminate many infected plants from a tree crop. There is no chemical product that directly kills viruses in plants; however, insecticides are widely used to protect plants or crops from further spread of viral diseases by insects. Virus-resistant varieties are available for some major or special crops. Fig. 3 shows some representative viral diseases on crops.

Fig. 3. Leaf mosaic, yellowing and stunting of pumpkin plants caused by watermelon mosaic virus (upper left), leaf mosaic and malformation of cucumber plants caused by cucumber mosaic virus, (upper right), potato calico disease caused by alfalfa mosaic virus (lower left), and leaf ringspot of hibiscus caused by hibiscus chlorotic ringspot virus (lower right). (Photos by Shouhua Wang)

CHAPTER 11: SPECIAL CIRCUMSTANCES

Desiccants, Defoliants, Growth Regulators

Desiccants, defoliants, and growth regulators are used in agriculture primarily as harvest aids and are typically applied pre-harvest**.** Desiccation and defoliation are related practices. Some pesticides can be used for both to achieve the goal of reducing foliar mass. However, desiccation and defoliation differ in some important respects. Desiccants dry out plants or plant parts. Desiccation products will cause the rapid drying and death of plant parts. They are useful on plants that are harvested for their seeds, fruits, or underground portions such as fleshy roots or tubers. The primary characteristic of desiccation is the rupturing of cell membranes allowing for the rapid loss of water. High temperatures and low humidity are the ideal conditions for applying desiccants. Defoliation, on the other hand, causes acceleration of leaf aging and abscission (separation) from the parent plants. Carefully defoliated plants remain healthy and capable of regrowth. Optimal conditions that maximize the effectiveness of defoliants are moderate to warm temperatures, moderate humidity levels, high moisture content in the leaves, and low nutrient levels in the leaves (esp. nitrogenous compounds).

Growth regulators are chemicals that mimic the activities of a plant's hormones. These products are specific in their action and vary widely in their use and application. For example, many natural plant hormones have been chemically modified to disrupt plant metabolism (photosynthesis, respiration, cell wall synthesis) and are used as systemic herbicides. Many growth regulators will reduce vegetative growth and promote flowering or fruiting. Others are used to accelerate the ripening of fruits. Still others are used to delay or eliminate flowering or bolting esp. in biennials. Since the action of growth regulators occurs inside the plant by altering its physiology, optimal conditions for applications are generally moderate temperatures, high humidity, limited air movement, and cloud cover. Additionally, peak conditions for absorption of product most often occurs in early morning or late afternoon.

Soil Fumigation

A fumigant is a chemical that under the right environmental conditions can exist as a vapor or gas. This allows for greater and more rapid penetration into a complex matrix like soil than liquids or aerosols. Fumigants play an important role in agriculture and turfgrass management. However, the chemical properties that make them so effective in managing difficult to control soil pests also may increase the risk of exposure to people who apply the chemicals, people who re-enter fumigated fields, and others who may be near the treated area. Before performing a fumigation, the applicator needs to understand clearly the hazards and problems associated with the use of fumigants as most are highly toxic to all forms of life including animals, plants, fungi, and microbes. Fumigation is a highly specialized operation that required equipment, skills, and techniques not generally used for other types of pesticide applications. Applying a fumigant can be time consuming and expensive, usually requiring more labor than other pest control methods.

Advantages of fumigation

- Fumigants are usually fast-acting and may result in the total eradication of the pest.

- Because fumigants are gasses, they diffuse deeper and more thoroughly into the soil and may reach pests that typically escape treatment when using conventional pest control materials or techniques.
- For certain soil-born pests, fumigation may be the only practical method available.

Disadvantages of fumigation

- The control achieved using fumigation is temporary with little if any residual action. Where adjacent untreated populations of pests are present, re-infestation can and usually does quickly occur unless further preventive measures are taken.
- Most fumigants are highly toxic and hazardous to the applicator, requiring specialized training and precautions during and immediately after applications.
- Fumigants must be retained in the gas form for some period of time to be effective, often calling for extra techniques and supervision.
- Fumigation should never be conducted by a single person, which increases labor costs of the treatment
- Fumigant activity may be significantly affected by extant environmental conditions such as soil moisture, temperature and humidity.
- Some commodities or pieces of equipment can be damaged by certain fumigants and must be removed or protected prior to application.

Several criteria should be considered in determining the need and suitability of fumigation for pest control. These include:

- Characteristics and habits of the pest
- Life stages of the pest
- Characteristics of the soil to be treated
- Hazards located in and near the treatment area
- Available pest management alternatives
- Established pesticide residue tolerances
- Label and law compliance

Factors to consider when choosing the proper fumigant for the treatment:

- Toxicity to the target pest
- Volatility and ability to penetrate (given the particular physical and chemical characteristics of the soil where the treatment is being applied)
- Any corrosive effects on equipment, flammability and explosive potential of product
- Warning properties and proper detection methods
- Effects on non-target species (seed germination, soil microbes etc)
- Residue tolerances
- Availability
- Ease of application
- Cost

For additional information on fumigation techniques and products applicators may wish to consult the "Soil Fumigation Manual" published by NASDARF and the NDA manual "Fumigation: The Use of Poisonous and Lethal Fumigants." (Full citations can be found in the useful reference list at the back of this manual).

Vertebrate Pests

Vertebrate pests are those pest animals that have backbones. Specific control measures vary for different species and are discussed in the sections for individual species.

Common vertebrate pest control practices include:

- 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: Repellants 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: Smoke bombs and internal combustion engines produce poison gases, including carbon monoxide, that can be used as fumigants. To be effective, all burrow

entrances must be blocked. When using smoke bombs, avoid areas near structures, hay stacks, etc.

- Aluminum phosphide fumigants: are available either as tablets or pellets. When applied in rodent burrows, they produce phosphine gas, which is deadly. Applied improperly, aluminum phosphide has resulted in numerous human deaths. To purchase, apply or supervise the use of this pesticide, applicators must successfully pass the state rodent burrow fumigation certification category.

Specific Vertebrate Pests

GROUND SQUIRRELS

Four species cause problems to crops and ornamental plants in Nevada: Richardson's, Belding's, Townsend's and California ground squirrels. They may also damage irrigation lines by chewing them or damage landscapes and buildings by burrowing. The best time for control is after they emerge from hibernation in early spring. At this time of year, there is little green vegetation, so the ground squirrels are more likely to accept rodenticide baits. Additionally, at this time of year, they have not yet mated and given birth. If control is postponed until later in the spring, there is green vegetation available and the ground squirrels are less likely to accept rodenticide baits. Advanced planning and preparation are essential. Attempting to control squirrels after they have reproduced can be frustrating, expensive and practically impossible. In order to eliminate exposure to non-target species, product labels for some rodenticide baits require application in bait boxes. Live trapping and subsequent euthanasia are also used to control ground squirrels. Check traps often and use caution to prevent unintended injury or death to non-target species. Strychnine cabbage bait, a restricted use pesticide, is well accepted but it must be used underground to protect non-target species. When applying grain baits, pesticide labels advise users to pre- bait. This is the process of applying untreated grain and monitoring to see if the animal takes it. If the animal isn't taking the untreated bait, it won't take the treated bait. As these animals can be carriers of bubonic plague, use care in handling sick or dead animals.

MOLES

Moles are insectivorous and are not a serious problem in Nevada. They eat soil-dwelling insects as well as other invertebrates like worms. Often found in urban areas, moles cause damage by building shallow surface tunnels that dislodge plants or push up turf. Trapping controls moles. Soil insecticides may be used to reduce the mole's food supply. This may encourage them to move off a property.

POCKET GROPHERS

Pocket gophers live underground and damage crops and ornamental plants by feeding on roots and sometimes foliage. Their burrows also cause damage to farm equipment and sprinkler

systems. Gopher activity is determined by fresh mounds that are typically horseshoe-shaped. Burrows are four to 10 inches underground. Strychnine grain bait, a restricted use pesticide, is most effectively applied in fall or early spring. The bait must be applied below ground. Hand-apply or use in a burrow builder for large areas. Synchronize application with neighbors for best results. Anticoagulant and zinc phosphide baits are also available. Trapping with kill traps is another commonly used control method for pocket gophers.

MICE AND RATS

These rodents eat and contaminate food and animal feed. They will both defecate and urinate on food and feed. They feed on alfalfa crowns and damage forage, seed and ornamental plants by girdling. They also cause structural damage by chewing both wood and wiring. They carry diseases contagious to humans, such as Rickettsial pox, bubonic plague and leptospirosis. No control method will be successful without excluding subsequent mice and rats from entering the site. Seal any opening over ¼-inch. Use good sanitation practices to remove any food supply that may attract these rodents, including seed for planting. Use rodent-proof containers to store all food and animal feed to prevent attracting and feeding these pests. Anticoagulant baits are most commonly used. Use care in placing these anticoagulant baits. Pesticide baits must be applied in approved bait stations. Snap traps can be effective, provided exclusion measures are also put in place. Baits for trapping include peanut butter plus oatmeal, bacon, gumdrops (for mice), nutmeats and dried fruit. Rat and mouse urine fluoresces under UV light. This can be used to locate their trails and commonly frequented areas. Bait and trap in these areas. Check traps daily and use care handling dead rodents.

VOLES

Voles are also referred to as meadow mice or field mice. They eat a wide variety of plants including grasses, forbs and seeds. When populations are high, voles will damage cropland through construction of tunnels and surface runways. They eat bark, primarily in the fall and winter. This can cause severe damage to trees and shrubs by girdling them. Voles breed throughout the year and may have five or more litters of young annually. Populations fluctuate and may reach extremely high densities. Habitat modification and toxicants are the primary means of vole management. Remove ground cover, weeds and litter around croplands to reduce populations. Zinc phosphide is the most common rodenticide used for vole control and is available on grain bait. Pesticide labels require that zinc phosphide baits be applied in the burrows and runways. Some product labels require the use of bait stations.

For all rabbit species, exclusion is the best control method

BLACKTAILED JACKRABBITS

Jackrabbits cause damage by feeding on crops and ornamental plants. A 45-degree angle cut to stems or branches is typical of rabbit damage. Jackrabbits don’t hibernate, so they are active all

year long. They have cyclic populations. They will travel long distances for food. The best control is exclusion. Jackrabbits are not easily trapped. Since they generally come in from surrounding rangeland, trapping and removing one simply allows another to take its place. Exclusion fences are recommended around haystacks, small areas, ornamentals and gardens. Shooting is an option as blacktailed jackrabbits are not protected, but it must be done only where it is safe and legal to do so. Repellents can be effective but must be reapplied on a regular basis and especially after rain or irrigation water wash them away. There are no registered poisons or fumigants for use on rabbits in Nevada. Strychnine (a restricted use pesticide) is no longer registered for jackrabbit control.

COCKONTAIL RABBITS AND WHITETRAILED JACKRABBITS

Cottontail rabbits and whitetailed jackrabbits are usually considered pests in the landscape. Control is similar to that for blacktailed jackrabbits. Exclusion is the best control option. While they can be trapped, trapping is not the best control method, and there are no toxicants registered in Nevada for control of either of these rabbits. The information provided for jackrabbits applies to both of these rabbits as well, with one exception: cottontail rabbits and whitetailed jackrabbits are game species in Nevada. Since they are designated game species, they can be shot only during cottontail rabbit and/or whitetailed jackrabbit hunting season, and you must have a hunting license.

Birds

Droppings, disease and consumption of crops and livestock feeds all make pests of certain birds. Caution must be used when dealing with bird pests, as many birds are protected under the Migratory Bird Treaty Act (MBTA). As with all other pests, you must first identify the pest causing your problems.

The following common bird pests are not protected by the MBTA:

PIGEONS (ROCK DOVES

Pigeons were introduced to the U.S. as domesticated birds and are now found throughout the country. They depend on human activities to provide them with food and shelter and have become serious pests in agricultural and urban areas. Pigeons feed on grains, seeds and garbage, and food is regularly provided intentionally by humans. Other damage results from pigeon fecal material and filth in areas where they nest, roost and loaf. Pigeons assemble sticks and twigs to form crude nests that are built in or on buildings and other structures such as billboards. Breeding occurs year-round but peak reproduction is in the spring and fall.

HOUSE SPARROWS

House sparrows were introduced to New England in 1850 and spread throughout the North American continent. They prefer human habitats, especially urban and farm areas. House sparrows feed mainly on grains and seeds but garbage and other refuse contribute significantly to their diet. Breeding can occur any time but March through August is most common. Problems are caused by feeding activities and fecal contamination in feed storage areas as well as inside and outside of other buildings.

EUROPEAN STARLINGS

These birds were introduced to North America in the late 1800's. Starlings cause problems at livestock facilities and in urban areas by consuming fruits and livestock feed. Holes or cavities in trees and structures serve as nesting sites and large roosts in buildings and trees cause health concerns and other problems due to filth, noise, and odor.

Bird Management

Exclude birds from nesting sites by closing openings that are larger than ¾ inch. Eliminate access to nesting and roosting sites by installing barriers, such as metal, netting or needle strips (porcupine wire). Roosting sites, such as ledges, can be eliminated by changing the angle to 45° or more. To discourage birds, use tactile repellents such as sticky bird glue on ledges and roosting areas. Recreational bird feeding attracts pest species. Limit the availability of food by storing livestock and other food in bird-proof facilities and containers. Prevent access to water sources.

Pesticides used for bird control are called avicides. These products are applied on baits and are classified as restricted use pesticides. Bait material may include small grains and whole kernel corn, depending on the bird species. The process of pre-baiting is recommended on avicide labels.

CHAPTER 12: NEVADA'S NOXIOUS WED PROGRAM

Weed Introduction and laws

The Nevada Revised Statute (NRS 555:130) authorizes the Nevada Department of Agriculture to designate and classify certain invasive and/or toxic plant species as "Noxious." A noxious weed is defined in NRS 555.005 as: "Any species of plant which is, or is likely to be, a public nuisance, detrimental or destructive and difficult to control."
The noxious weeds list can be found in the Nevada Administrative Code NAC 555.010.
Once a weed is classified as noxious, it is placed in one of three categories. Category placement is dependent upon the weed's distribution and establishment levels across the state. The three categories are A, B, C:

1. "A": Weeds that are generally not found or that are limited in distribution.
2. "B": Weeds that are generally established in scattered populations in some counties of the State.
3. "C": Weeds that are generally established and generally widespread in many counties of the State.

After the weed has been designated and classified it is by state law that control measures must be implemented to eradicate or mitigate the weed's further spread. As stated in NRS 555.150: "Every railroad, canal, ditch or water company, and every person owning, controlling or occupying lands in this State, and every county, incorporated city or district having the supervisor and control over the streets, alleys, lanes, rights-of-ways, or other lands, shall control weeds declared as noxious as provided in NRS 555:130 in a manner specified by and whenever required by the State Quarantine Officer".

Currently there are over 40 weed species listed as noxious but as other invasive plant species encroach from bordering states the list is subject to revisions. Although revisions to the list requires administrative authority, citizens of the state can request a revision by submitting a written request describing the need and reason for the change. The requested change can be the inclusion of a new species, the reclassification of a species currently in listed in the A, B, and C categories, or the removal of a noxious weed species which has infested the state to such an extent eradication and/or mitigation of it is not possible. Once the formal request has been received, it is the discretion of the Noxious Weed Coordinator to deny or move the request to the Board of Agriculture for approval. If approved, the proposed change must go to workshop and hearing. After workshop and hearing, a motion must be made and favored again by the Board of Agriculture for it to be moved to the Legislative Council Bureau (LCB) for approval. If the LCB approves the change it is signed into law by the Attorney's General.

However, it is important to know that some counties have state authority to require landowners within certain counties to control certain weed species not listed by the state as noxious but deemed significantly problematic. These are called "Weed Control Districts." There are currently eight Weed Districts in the Nevada. Some species controlled in these districts, not listed as noxious, are Dodder *(Cuscuta species)*, Field Bindweed *(Convolvulus arvensis)*, Curly Dock

(Rumex crispus), and Wild Licorice *(Glycyrrhiza lepidota).* These would be referred more aptly as "Nuisance" weeds which are often defined as "Any plant growing outside of its intended place." However, many nuisance weeds can be just as invasive as many noxious weeds. Take for example Cheat Grass or Tumble Weed. Many people assume these weeds are noxious simply due to their wide spread infestation across the state. Considering this, it is important to recognize that since state law requires the control of noxious weeds it would not be realistic to place a weed on the list, such as Cheat Grass, when the likelihood of control is not realistic or feasible. However, although nuisance weeds are not regulated by the state as noxious weeds are, be that nuisance weeds are so wide spread much of the work that pest control operators will encounter are that of nuisance weed control.

Some common nuisance weeds that a pest control operator should be aware of are:

- Cheatgrass *(Bromus tectorum)*
- Purslane *(Portulaca oleracea)*
- Flixweed *(Descurainia Sophia)*
- Lambsquarter *(Chenopodium album)*
- Pigweed *(Amaranthus species)*
- Filaree *(Erodium cicutarium)*
- Wild Oat *(Avena fatua)*
- Russian Thistle *(Salsola species)*

Additionally, a few noxious weeds a pest control operator should be aware of are:

- Puncturevine *(Tribulus terrestris)*
- Canada thistle *(Cirsium arvense)*
- Leafy spurge *(Euphorbia esula)*
- Poison Hemlock *(Conium maculatum)*
- Russian knapweed *(Centaurea repens)*
- Scotch thistle *(Onopordum acanthium)*
- Hounds Tongue *(Cynoglossum officinale)*
- Hoary cress *(Cardaria draba)*
- Perennial Pepperweed *(Lepidium latifolium)*
- Yellow Star Thistle *(Centaurea solstitialis)*
- Medusahead *(Taeniatherum caput-medusae)*

Integrated Pest Management (IPM)

One of the primary reasons a pest control operator should be familiar with many species of weeds is to correctly determine the most effective method of control. As with any pest controlled, correct identification of the pest is the first step in an IPM program. Correct identification leads to knowing the pests' lifecycle and growth characteristics which in turn assists with developing a pest management plan.

For assistance with correct weed identification, contact the Nevada Department of Agriculture's Noxious Weed Coordinator.

Physical/Mechanical Controls

Once the weed has been properly identified, a pest control operator must determine what control method would be the safest, and most effective, yet simultaneously meeting the needs of the client. For example, if the client is opposed to chemical controls physical and mechanical controls may offer an environmentally safe alternative. Such controls consist of:

- Hand pulling
- Digging
- Cutting
- Mowing
- Tilling
- Disking

However, it is important to know that with some weed species physical or mechanical controls can be effective while with other species such controls can stimulate growth and spread the problem even further. A good example of such a species is Perennial Pepperweed *(Lepidium latifolium),* which spreads by seed but also by propagative root fragments. In such a case, if an infestation of Perennial Pepperweed was to be tilled or disked, allowing for the roots to be broken apart and spread, each root fragment could potentially become a new infestation. Conversely, if an infestation of an annual weed, such as Yellow Star Thistle, was to be continually tilled prior to seed production it could over time be an effective method of control. When considering physical or mechanical controls it is also important to consider the associated costs such as labor, disposal, and equipment costs. Fortunately, these associated costs can often be mitigated by timing the control properly. Take for example the removal of Salt Cedar (Tamarix species). This small bushy tree can be physical removed with a pair of hand loppers when small, but if allowed to reach its mature size of 20', not only does the labor and disposal costs increase dramatically but the removal of a mature tree stimulates seed germination and sucker growth increasing the length of time to remove it entirely. Another example is the removal of Russian thistle *(Salsola species).* If manually removed when small, the remaining plant will blow away and deteriorate. However, once the plant is 4' around, its removal requires disposal costs.

Cultural Controls

Cultural weed control consists of habitat modification such as the utilization of mulches, improved drainage, prescribed burns, or fertilizer restrictions. The benefits of cultural modifications are not always easily seen but can yield cost effective, long term preventative results when done prior to an infestation. Take for example the use of decomposing mulches such as leaf and stem debris. Not only does the mulch restrict light preventing seed germination of annual weeds it also retains water, limits soil erosion, and provides soil nutrients. Additionally, in areas of excessive drainage invasive weed species such as Hoary Cress (Cardaria spp.) may develop and spread following the flow of water which over time may impede or

restrict irrigation canals. Fertilizer restrictions limit excess nutrients from reaching bodies of water that may contribute to an abundance of aquatic weeds and algae that causes eutrophication which depletes oxygen from the water negatively impacting desired aquatic species and water quality.

Biological Controls

Biological controls are host specific insects, fungi, and bacteria that occupy the weed species needing control by feeding upon it directly, utilizing its nutrients, or using it as an area for reproduction. In cases of insects, such as the Russian knapweed gall midge *(Jaapiella ivannikovi)* the midge lays her eggs in the top portions of the Russian knapweed. The developing eggs create a gall just below the flower portion preventing the flower from developing into a seed. Over time the plant density will decrease from declining seed dispersal.

Chemical Controls

Using IPM techniques often results in a reduction in the necessity for pesticides. However, the judicious use of chemical control can be the most effective option, especially in the case of very invasive species that can rapidly populate and cause considerable damage to a crop. It is paramount to the success of any IPM strategy that the applicator understands the utility and limitations of all potential techniques in order to maximize efficacy and cost effectiveness.

Useful References and elinks

- Nevada Department of Agriculture Plant Pathology Program: http://agri.nv.gov/Plant/Plant_Pathology/Plant_Pathology_Home/
- UC Davis IPM website: http://ipm.ucanr.edu/
- Pacific Northwest Handbook: https://pnwhandbooks.org/plantdisease
- Pacific Northwest Handbook https://pnwhandbooks.org/weed
- Pacific Northwest Handbook https://pnwhandbooks.org/insect
- American Phytopathological society: http://www.apsnet.org/Pages/default.aspx
- National Plant Diagnostic Network: https://www.npdn.org/home
- Blecker, LA and Thomas JM (2012) Soil Fumigation Manual. A National Pesticide Applicator Certification Study Guide. Published by the National Association of State Departments of Agriculture Research Foundation (NASDARF).
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