Pest Management Overview

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Figure 1. **Leaf-beetle larvae eating saltcedar, an example of biological pest control.**

INTRODUCTION

Pest management is a system of integrated preventive and corrective measures to reduce or prevent pests from causing significant harm to humans or the environment (Bennett et al., 2005). The goal of pest management is to achieve desired outcomes at the lowest possible cost and with the least risk to humans and the environment. Pest management boils down to affecting those elements of the environment that contribute to an invasive species' ability to reproduce, survive, and thrive. These elements, such as food, water, and shelter, are referred to as habitat. When habitat conditions are ideal for pests, they thrive and reproduce, resulting in negative impacts to humans and the environment.

Pests are undesirable organisms, such as insects, bacteria, fungi, nematodes, weeds, viruses, or vertebrate animals, that harm humans or human interests (EPA, 2014). Pests can damage, devalue, or destroy agricultural crops, food stores, lawns, gardens, human structures, clothing, and furniture, as well as negatively affect terrestrial and aquatic ecosystems. Additionally, pests can negatively impact the health of humans and surrounding animals, as well as detrimentally invade and push out native plant species and alter the surrounding environmental factors (soil health, nutrient content, available moisture, fire events, etc.) to further displace native plant species and wildlife. Even desirable species may become pests if their actions or impacts become problematic, or if populations become excessive and/or expand into areas where conflicts arise. Pest problems occur nearly everywhere and can affect every living thing on earth to varying degrees.

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Table 1. General Steps to Address a Pest Problem	
1.	Define the problem and accurately identify the problem species.
2.	Establish desired outcomes to help guide pest management efforts and determine management success.
3.	Gather information on the biology, behavior, habitat, and environmental conditions that promote and support pests.
4.	Learn about various control methods and select practices to achieve successful pest management.
5.	Select and apply the most effective control practices first.
6.	Monitor the success of selected practices and record what was done and how well it worked. If the selected practice is not producing desired outcomes, change management practices to reach your desired outcomes.

A variety of methods exist to manage pests that include using natural, biological, chemical, cultural, genetic, mechanical, physical, and regulatory controls. Natural controls (e.g., weather or topography) are environmental factors that limit the number and distribution of pests. Biological controls use natural enemies to injure or consume target pests to manage their population sizes. Cultural practices (i.e., how and when something is done) influence pest infestations directly or indirectly by making the environment less suitable for pests but more suitable for desirable species (humans, crops, animals, etc.). Mechanical and physical controls include the use of tools to directly impact populations, or limit/alter access to environmental factors necessary to support pest populations. Natural or synthetic chemicals are also commonly used to manage pests. When pest populations become particularly dangerous to human health and safety or to human enterprises, regulatory control efforts (e.g., quarantine or eradication programs) use federal and state laws to improve management practices to prevent further pest spread and new infestations.

COSTS OF PESTS AND PEST MANAGEMENT

Pest damage to crops, industry, environment, health, and human structures costs billions of dollars every year (Meyer, 2004). The food industry continuously monitors for pests, such as listeria, salmonella, and other microbes, in foods intended for public sale. The estimated costs for food safety incidents (notifying the public, product recalls, related lawsuits) were estimated at $7 billion annually in the U.S. (Hussain and Dawson, 2013). Prevention and treatment costs related to humans infected by the mosquito-borne West Nile Virus amounted to $778 million in the U.S. (1999–2014), with approximately 1,200 virus-associated deaths (Staples et al., 2014). Various types of pests also negatively affect human-made structures such as buildings. Su (2002) estimated annual economic losses at $11 billion due to termites damaging wooden structures throughout the U.S. Additionally, costs to manage weeds for commercial and residential properties have reached $99 billion in the U.S., and this trend is expected to grow at an annualized rate of 4.4% over the next 5 years (IBISWorld, 2019). Weeds have a negative economic impact on livestock producers, costing the U.S. more than $2 billion annually (DiTomaso, 2000). Vertebrate pests such as mammals and birds cost an estimated $46 billion annually in damage and control costs (Pimental, 2007). In large-scale agricultural production, one of the most common ways to control agricultural pests is using pesticides. Pesticide production is a $32 billion industry each year, with five billion pounds of pesticides applied to crops worldwide (Sexton et al., 2007). Additionally, pesticide costs for farm production have increased to more than $70 per acre annually due to increasing demands for higher crop yields and quality, with fewer acres available to farmers throughout the U.S. (Schnitkey, 2019).

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is a process that seeks a balanced application of pest control methods for improved pest management success in an environmentally safe and sustainable manner. Integrated pest management emphasizes a balanced combination of pest management practices that target pests and their environment while minimizing the damage, risks, and costs associated with implementing management practices. Pests are controlled most successfully in the long term when managed using an IPM approach. For example, treating the causes of pest infestations rather than only treating symptoms is essential to success (Hobbs and Humphries, 1995). Integrated pest management promotes healthy and sustainable ecosystems that support desirable organisms (i.e., humans, animals, agronomic crops, natural ecosystems) but not pests. Effective IPM strategies successfully integrate a combination of control methods to reduce pest damage below the economic, ecologic, or tolerance thresholds, which may vary greatly by location and management objective. When pest impacts rise above a specific threshold, it becomes financially beneficial to invest in control treatments to reduce pest population density or the extent of their impacts. The ideal outcome of IPM is a healthy and productive ecosystem that functions properly, is self-sustaining with the ability to resist pest infestations in the future, has the capacity to recover when disturbed without requiring external inputs, and provides the goods and services humans need. Fundamental to IPM is the use of preventive measures, pest and damage assessment, and integration of appropriate actions to manage pests. For further information on integrated pest management, visit https://aces.nmsu.edu/pubs/howto/howto.html.

DEFINING THE PROBLEM

Managing some pest problems may be easy, while others are much harder and require repeated, costly efforts. Regardless of the pest, carefully assessing the problem and underlying causes and accurately identifying the pest responsible will help managers select effective control methods. Evaluate the situation and environmental conditions that led to the pest infestation. Inspect the infested and surrounding areas to understand the size of the pest problem prior to implementing management. When the habitat is suitable for pests, it encourages insect and vertebrate pest infestations. For example, when addressing weed plant infestations, understanding "habitat" conditions includes considering the availability of water and sunlight, soil conditions, the timing and amount of ground disturbance, and inadequate management practices that may have fostered an ideal environment for pest infestations. Since "an ounce of prevention is worth more than the cure," these initial efforts will prove useful in developing your pest management objectives. Table 1 describes the general steps used to address a pest problem.

PEST IDENTIFICATION

Since some desirable species in New Mexico may look like invasive pest species, correctly identifying the pest promotes effective pest management. If you have difficulty correctly identifying your problem pest, contact your county's Cooperative Extension Service office (https://aces.nmsu.edu/county/) for assistance. Your County Extension Agent will help you identify the pest and provide information on how to manage it. Additional assistance is available through the New Mexico Department of Agriculture, New Mexico State University Extension Specialists, local Soil and Water Conservation Districts, the New Mexico Department of Game and Fish, and the Natural Resources Conservation Service.

ESTABLISHING PEST MANAGEMENT OBJECTIVES

Define pest management objectives to help you select management practices that will achieve those objectives. In defining objectives, identify any obstacles that might hinder their success. Develop additional objectives when unforeseen problems arise. Without objectives, it is difficult to measure management effectiveness and know when pest management efforts are successful.

UNDERSTANDING THE BIOLOGY AND BEHAVIOR OF PEST SPECIES

Understanding the pest species' biology and behavior is useful for selecting management practices appropriate for your situation and for managing the problem without harming the environment. Gathering information on the pest's life span, reproduction, number of offspring, preferred habitat, and general behaviors helps you tailor your management specifically for that pest. Information regarding the biology of many insect, plant, and vertebrate pests can be found on the NMSU College of Agricultural, Consumer and Environmental Sciences publications website (https://aces.nmsu.edu/pubs/). Additional pest information is available on government and education websites (i.e., website URLs that end in ".gov" or ".edu"). The more you know about a problem pest, the better equipped you will be to determine the cause of pest problems, develop an effective management plan, and achieve successful pest management outcomes.

APPROACHES TO PEST MANAGEMENT

The more you know about the biology and behavior of the pest, the easier it will be to select the most effective and sustainable pest management strategy. Learn about the various methods and tools available to address the pest problem. Use the size of the pest infestation, amount of damage, and environmental considerations to inform your management approach. Before implementing any pest management practices, consider whether your proposed management practices will achieve your objectives, improve or maintain the health and well-being of surrounding humans and animals, and protect the environment. Basic pest management practices that apply to all pest problems include pest prevention, suppression, and habitat reduction.

Prevention/Suppression/Eradication

Preventive measures are economical and environmentally responsible methods that reduce or eliminate the conditions that promote pest infestations. Frequently cleaning areas where pests are likely to live prevents pest establishment. Suppression methods restrict pest activity and population growth of existing infestations. Quickly applying pest control measures while pest numbers are low suppresses pest growth. Eradication methods typically occur at a small scale (e.g., a building, a home landscape) and are applicable for a variety of situations, including human health, well-being, and safety. Once the pest population is eradicated, it is important to continue preventive measures to avoid re-infestation or invasion by other pests. Under some circumstances, eradication programs at larger scales may be necessary; however, they often require regulatory control methods.

MANAGEMENT AND CONTROL METHODS

Management practices are categorized into biological, chemical, cultural, genetic, mechanical/physical, and regulatory control efforts. Each category addresses some aspect of habitat (food, water, and shelter) or population management (reproduction and survival) designed to meet pest management objectives.

Biological Control Methods

We modify natural habitats to meet our needs. In the process, we repeatedly disrupt existing ecosystems and create

environments favorable to pests. Biocontrol uses a non-pest organism to control a pest. Some biocontrol agents are native while others are from foreign countries. Before foreign biocontrol agents are released for use in the U.S., they are extensively researched to ensure that they do not cause damage to crops or the environment.

Types of biocontrol agents include predators, parasites, pathogens, and competitors, among others, that when released cause varying levels of injury to target pests (Figure 1). One biological control example is establishing garlic, dill, marigolds, or other plants that attract ladybugs. After arrival, ladybugs also eat aphids and other small pests in the larval stage of development.

Legal restrictions apply to the use of certain biological control agents at international, national, regional, and state levels. Before using biological control agents, contact appropriate experts for important information about their use. The New Mexico State University Cooperative Extension Service and New Mexico Department of Agriculture have Specialists, County Agents, and other professionals who can provide you with information on biocontrol methods.

Chemical Control Methods

Chemical pest control uses a combination of substances, often referred to as active ingredients, applied to pests or their food to disrupt their life cycle. Chemical pest control can be as simple as cleaning tabletop surfaces with bleach before preparing food. Most treatments fit within one of the pesticide categories that include herbicides, insecticides, rodenticides, bactericides, fungicides, and larvicides. Federal, state, and local pesticide laws and regulations help protect the environment and human health while garnering the benefits of pest control. Before pesticides become available for sale in the U.S., they must be studied and approved by the Environmental Protection Agency under the Federal Insecticide, Fungicide, and Rodenticide Act and the Food Quality Protection Act. Proposed pesticides go through years of scientific evaluation to make sure they achieve their intended purpose without causing unreasonable risk to human health and the environment (Cardno, 2015).

Two major categories of pesticides are general use and restricted use. General-use (unrestricted) pesticides like glyphosate are available to the public and do not require a license or additional training to purchase and apply. In contrast, there are specific pesticides that may contain active ingredients that represent greater risk of harm to the environment or humans. The EPA classifies these chemicals as restricted-use pesticides (RUPs). Pesticide labels contain important information for safe and responsible use. Restricted-use pesticides like paraquat can only be purchased and applied under the supervision of a licensed pesticide applicator. In the state of New Mexico, a pesticide applicator's license can be acquired through testing and training approved by the New Mexico Department of Agriculture. To maintain a pesticide license, applicators are required to obtain continuing education units (CEUs), also commonly referred to as continuing education credits. Many county Cooperative Extension Service offices host pesticide CEU workshops. The New Mexico Department of Agriculture posts a calendar with CEU opportunities at http://www.nmda.nmsu.edu/home/divisions/aes/pesticides/workshops/. More information on how to obtain a pesticide applicator's license can be found at http://www.nmda.nmsu.edu/pesticides/applying-license. For further information on pesticide registration, see https://www.epa.gov/pesticide-registration.

When you purchase a product to address a pest issue, it is crucial to read and follow the directions and restrictions on the pesticide label found on the product before every application. The pesticide label provides instructions that you are required by law to follow when using that product. Labels provide information on hazards, first aid, and necessary personal protective equipment (PPE) for the safe use of the product. The labels give important instructions on the safe transportation, handling, storage, and disposal of the product. Labels on non-pesticide items such as mechanical devices (e.g., animal traps) are also legally binding. In addition, organic pest control products have labels for safe and successful applications, excluding do-it-yourself mixtures. Even before using household chemical products (e.g., bleach, vinegar), investigate the potential for environmental contamination and human health and safety considerations.

Sources of information regarding pesticides include:

- National Pesticide Information Center (NPIC): http://npic.orst.edu/
- Environmental Protection Agency (EPA): https://www.epa.gov/pesticides
- EPA Pesticide Labels: https://www.epa.gov/pesticide-labels
- EPA Introduction to Labels: https://www.epa.gov/pesticide-labels/introduction-pesticide-labels
- Poison Control Center: https://triage.webpoisoncontrol.org/#/exclusions
- OR CALL Poison Control at **800-222-1222**

Pesticides and the Environment

The environment includes all living and non-living things, including air, water, soil, plants, wildlife, people, and animals, as well as natural and human-built structures and ecosystems. Knowing the potential effects of pesticides on the environment will help you make better-informed decisions about when and how to use them safely. You should ask the following questions each time you use a pesticide and make decisions based on the answers:

1. Where does the pesticide go when applied or if spilled?
2. What impacts may the pesticide have on areas it may reach?
3. What can be done to minimize potential harm to the environment?

Figure 2. **Applying herbicide to the cut stump of a mesquite shrub, an example of chemical pest control.**

These questions lead to additional questions according to the situation and should be addressed before using pesticides. Taking an IPM approach ensures that pesticides are used only as a last resort if other management methods have failed. In this way, IPM approaches reduce pesticide inputs and potential negative effects of pesticides on human health and the environment.

Planning Pesticide Applications

Make a plan before applying pesticides. Study pesticide labels and NMSU guidance documents for each pest and the surrounding environment; for example, pesticide application restrictions increase with proximity to surface water. Acquire personal protective equipment (PPE) and pesticide cleanup supplies to limit human and environmental exposure. Determine appropriate pesticides, application methods, necessary equipment, appropriate conditions for application, and special safety considerations to limit the potential for environmental contamination. Learn effective and safe pesticide equipment cleaning procedures and container disposal. Coordinate pesticide application timing with other types of pest management practices (e.g., habitat modification) to improve pest management success and sustainability.

Pesticide application equipment and methods are critical to successful pest management. Select a pesticide sprayer and application method specific to each type of pest to maximize application effectiveness and minimize environmental damage and costs. Calibrate pesticide equipment prior to application to ensure that the amount of pesticide applied is within pesticide label requirements yet enough to control the pest without excessive pesticide application. Selecting appropriate sprayer pressure, nozzles, and drift retardant along with only applying pesticides when the weather supports safe application minimizes pesticide drift and non-target or off-site damage (Figure 2).

Cultural Control Methods

Use cultural methods to reduce pest establishment, dispersal, reproduction, and survival. Cultural methods use combinations of biological, chemical, genetic, mechanical, and physical controls that focus on timing, sequence, and intensity of the IPM methods necessary for maximum effect. Mowing, pruning, irrigation management, plant variety selection, and timing of planting or harvesting are examples of cultural methods that improve the ability of desirable plants to outcompete pests. Classic cultural practices in agriculture include selecting cultivation practices that not only are appropriate for the specific crop but also benefit environmental processes and further reduce pest problems. Sanitation is a cultural practice that includes removing diseased plants and debris piles that harbor insects or vertebrate pests. Additional sanitation practices include maintaining clean work and storage facilities, keeping equipment and materials off the ground, and fixing leaky water pipes to limit water available to pests. Effective cultural pest management requires correctly applying effective management practices at optimal times.

Genetic Control Methods

Some plants and animals naturally resist certain pests. Use these pest-resistant plants and animals to minimize the need for additional management practices such as pesticide applications. For some plants and animals that lack natural resistance, improved plants and animals are available (e.g., blight-resistant tomatoes). Selective breeding and genetic advances develop improved pest resistance or pesticide tolerance. Humans have selected plants and animals with the most desirable genetics since the beginning of agriculture.

Mechanical and Physical Control Methods

Mechanical and physical pest control methods modify pest habitat or directly kill pests. Mechanical control methods include digging weeds (Figure 3), trapping rodents, and sterilizing soil. Physical control methods include barriers that prevent weeds from surfacing (Figure 4) and insects or vertebrates from entering clean areas. Initial costs of pest exclusion methods can be expensive and require repeated

Figure 3. **Using cultivation to control weeds in chile, an example of mechanical pest control.**

Figure 4. **Using mulch to limit weed establishment in a vineyard, an example of physical pest control.**

installation or replacement as they wear out, but they usually provide long-term economic and pest control benefits.

Regulatory Control Methods

Regulatory agencies such as the U.S. Department of Agriculture, Centers for Disease Control and Prevention, and Department of Homeland Security, as well as their state counterparts, can enforce regulations. Regulatory control addresses pest problems that cause significant human health and safety concerns or widespread and severe damage to agricultural crops, animals, or the environment. Regulation compliance helps people avoid causing large pest problems. Primary regulatory control measures include coordinated quarantine and eradication methods to contain and, where possible, eliminate pest problems.

MONITORING PESTS AND MANAGEMENT OUTCOMES

Effective pest management requires constant awareness and frequent monitoring. Early detection and rapid response help reduce pest management costs and improve management outcomes. Monitoring large pest problems at multiple locations helps track the speed and direction of pest movements. This knowledge allows managers to organize resources and make coordinated pest management efforts. Monitoring at the right time and location is equally important. Pest problems can develop quickly. Pests may be apparent only during particular seasons or at specific stages of their life cycle. Knowledge of the biology and behavior of pests improves the ability to monitor and react to new information, as well as adapt and implement effective pest management strategies as pest populations develop.

Keep records of pest populations, pest management actions, and pest responses to past actions to inform future management decisions. Pest monitoring records reveal past treatment effectiveness and identify where to adjust future management actions. The pest situation influences which information to record. General examples of records include answers to the following questions:

- What was the problem?
- What management actions were taken?
- How were these actions applied?
- When and where were these actions made?
- What resulted from these management actions?

Further recordkeeping guidance is available at https://pesticidestewardship.org/records/benefits-of-recordkeeping/. State regulations require that specific information be recorded when pesticides are applied. A printable form is available at http://www.nmda.nmsu.edu/wp-content/uploads/2011/12/Record-form1.pdf.

PERSONAL SAFETY

Your personal safety is most important in accomplishing your pest management objectives. Product labels, personal protective equipment (PPE), and increasing knowledge through continuous education helps protect you, others, and the environment. Basic PPE involves wearing long-sleeved shirts, long pants, closed-toe footwear, non-absorbent (usually latex) gloves, and face and eye protection to limit the chances of personal injury. For your safety, it is very important to take time to learn about the proper use of your PPE.

COLLABORATION

When pests infest large areas, regional cooperative pest management groups are essential to providing an effective response. Individual pest control efforts are useful and should continue as needed. However, without information and education on controlling pests at a larger scale,

the pests will continue to spread and re-infest previously treated areas. Successful regional pest management can be achieved when people work together, pool resources, and inform community members and agencies on the successes and failures of specific pest management techniques. People working together toward a common goal improves individual and group motivation over the long term.

SUMMARY

A systematic approach to pest management saves time and money and results in better pest management outcomes. Defining the problem and its causes, identifying pests accurately, understanding pest biology and behavior, developing clear objectives, and applying appropriate management practices are fundamental to pest management success. Respond to pest problems and begin monitoring and keeping records as soon as a pest problem is identified. Select the most effective combination of integrated pest management practices that achieves your objectives, ensures that pests do not return, and minimizes negative effects of pests and pest management practices on the well-being of humans and the environment. Review management effectiveness repeatedly to identify the most and least effective practices, and use this information to improve future management. The NMSU Cooperative Extension Service provides workshops and educational materials to help individuals and groups manage pests in their crops, pastures, rangelands, homes, urban gardens, livestock, pets, and many other areas. For more information regarding pest management, visit the NMSU CES website at https://extension.nmsu.edu.

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