FORTIFYING FARMS AND RANCHES AGAINST WEED INVASION
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DEATH, TAXES...AND WEEDS?

“In this world nothing is said to be certain, except death and taxes.”
— BENJAMIN FRANKLIN (1789)

Although there is a lot of truth to the above statement, anyone who has made a living in agriculture on a farm or ranch would probably agree that the list of certainties could easily be expanded to include weeds. Since the time of the earliest U.S. settlers, weeds have had a constant presence. The persistence and prolific reproduction of weeds ensures that each year farms or ranches will have a new battle with weeds.

THE WEED MANAGEMENT TREADMILL

The traditional approach to weed management on most farms or ranches is similar to a person running on a treadmill. A treadmill allows a person to run or walk while staying in one place. As the exercise deck cycles around and around, the user exerts energy to maintain the set pace, but never really goes anywhere.

Agricultural producers spend a great deal of resources (time and money) on what can be thought of as a weed management treadmill. The weed treadmill is always in motion. Treadmill speed is controlled by how well or how poorly the weeds were managed in the past. Regardless of speed, failure to keep pace in the annual battle with weeds immediately impacts profitability. Because of the economic impact, producers, agribusinesses, and scientists have focused primarily on tools related to weed management.

Historically, the emphasis on weed control has largely been effective because individual weed species that infest a given farm or ranch have tended to remain constant. Although some years are more suited to weed growth than others, the overall weed problems are often passed from one generation to another and from one landowner to the next. In the modern day, the weed situation, and consequently the approach needed for weed management, has begun to change.
1 Weed management has a long history on farms and ranches in the U.S. and, in the present day, has integrated multiple techniques.

2 Weeds such as green foxtail, common dandelion, and field bindweed are well-established on most farms and ranches in the western U.S. and require annual management to minimize impacts.

3 Like running on a treadmill, the persistence and prolific reproduction of established weeds on farms and ranches requires regular investment of resources every year to minimize impacts and protect profitability.
Advances in transportation, technology, and communication allow agricultural producers to purchase products from a variety of distant sources. This higher degree of exchange between operations across county, state, and even country borders creates a highly efficient mechanism for long distance weed dispersal.

**SOME EXAMPLES**

2 Russian Knapweed – aggressive creeping perennial introduced via alfalfa seed; forms dense patches that suppress crop and forage plant growth; not readily consumed by livestock; toxic to horses.

3 Yellow Starthistle – short-lived simple perennial introduced in contaminated seed; now infests millions of acres in the West; aggressively depletes soil moisture, lowers quality and yield of forages; spines cause livestock to avoid infested areas; toxic to horses.

4 Musk Thistle – biennial introduced in ship ballast; reduces quality and yield of forage plants; sharp spines deter forage consumption by livestock.

5 Jointed Goatgrass – winter annual grass weed introduced as a contaminant in wheat seed; causes significant yield losses in wheat; seed similar in size to wheat, making separation difficult; contaminated wheat subject to dockage at market.
THE CHANGING FACE OF WEEDS

Throughout much of western agricultural history, farms and ranches were relatively small, self-sustaining, diversified operations where most, if not all, needs could be met by an individual and a few neighbors. Modern advances in transportation, technology, and communication have allowed farms and ranches to become larger and more specialized. Agricultural commodities that were previously produced and consumed on-site, or within a local area, are now transported to other states and even other countries. Local agricultural producers also purchase products from a variety of distant sources. This high degree of commodity exchange between operations within the U.S. and the world creates a highly efficient mechanism for long-distance weed dispersal. No longer are farms and ranches exposed only to weeds from their local area, such as the native buffalobur shown below, but are subject to invasion by non-native species from around the globe. The changing face of weeds is obvious as operators now find themselves in a battle against new weeds from almost anywhere in the world.

The problem with newly introduced weeds is that they are often more aggressive, persistent, harmful, and more difficult to control than those historically managed. Any farm or ranch in the western U.S. has at least a few weeds that have come from other places that are now having a negative impact on profitability. Regardless of the number of weeds that currently infest a farm or ranch, there are literally hundreds of new weeds in neighboring farms, towns, counties, states, and even countries that threaten to gain entry.
Professionals in medicine have long advocated prevention as a health management strategy. In agriculture, prevention is the most effective tool to keep new weed threats from becoming permanent fixtures on a farm or ranch.

A comprehensive weed prevention program consists of the following core weed prevention tactics: prevent arrival, prevent establishment, and prevent spread.

THE CASE FOR PREVENTION

“An ounce of prevention is worth a pound of cure.”
— BENJAMIN FRANKLIN (1735)
OVERVIEW OF WEED PREVENTION

“Preventive weed control encompasses all measures taken to forestall the introduction and spread of weeds.”
— NATIONAL ACADEMY OF SCIENCES (1961)

To be successful, weed prevention requires education and becoming aware of the nature and extent of the problem. The process consists of the following core weed prevention: prevent arrival, prevent establishment, and prevent spread. Every plant that has the potential to become a weed on a farm or ranch will fall subject to one of these categories. The goal of an agricultural producer for most of the world’s weeds is to prevent arrival. Weeds that slip through the cracks and arrive on a farm or ranch become subject to the second line of defense, prevent establishment. The only recourse for weeds that become established is to minimize the impact of the weed by preventing spread. The sections that follow detail the steps of weed prevention and how they can be integrated into the weed management programs of agricultural operations in the western U.S.

CORE WEED PREVENTION TACTICS

including healthy diet, exercise, avoiding harmful substances such as tobacco, misuse of drugs and alcohol, improves longevity and quality of life.

Health problems, after onset, often stay with a person throughout the remainder of his/her life. After a new weed is introduced to a farm or ranch, experience has shown that eradication is nearly impossible, and a lifetime of managing that weed begins. Investments in weed prevention can help farmers and ranchers avoid the added expense and labor that come with managing weeds after they have invaded.

To deal with new weed threats, a producer has two options: to be reactive or proactive. In the reactive strategy, a producer waits until after a weed arrives, becomes established, and impacts production before control measures are implemented. Due to their persistent and aggressive nature, these weeds will likely become permanent fixtures on the operations where the reactive strategy is employed. The proactive strategy is geared toward prevention; that is, taking steps to keep the weeds from becoming a problem in the first place.
FORTIFYING FARMS AND RANCHES AGAINST WEED INVASION

Water is the life-blood of agriculture in the western U.S. Although some areas receive sufficient annual rainfall to sustain crop production, many producers require irrigation to meet crop and livestock needs. This need is often met through extensive water delivery systems composed of lakes, reservoirs, rivers, canals, ditches, and pipelines.

PREVENTING WEED ARRIVAL

Preventing the arrival of new weeds on a farm or ranch implies vigilance for sources of invasion. Some avenues of arrival include: water, wind, animals, products, vehicles and equipment, intentional introduction, and development of herbicide resistance (i.e., invasion from within).

WEED ARRIVAL BY WATER

Water is the life-blood of agriculture in the western U.S. Although some areas receive sufficient annual rainfall to sustain crop production, many producers require irrigation to meet crop and livestock needs. This need is often met through extensive water delivery systems composed of lakes, reservoirs, rivers, canals, ditches, and pipelines. Long-
Although some areas of the West receive sufficient annual rainfall to sustain dryland crop production, many producers require irrigation to meet crop water needs.

The need for water in the western U.S. is often met through intricate water delivery systems composed of lakes, reservoirs, rivers, canals, ditches, and pipelines. Long-distance water transport is also a very effective avenue for the spread of weed seed.

Irrigation water that arrives on a farm or ranch has normally traveled through miles of waterways, many of which traverse weed infested areas. Weeds such as Russian olive, poison hemlock, and purple loosestrife often grow along the banks of canals, ditches, and rivers where mature seed and other reproductive parts can fall into the water and be carried downstream.

distance water transport is also a very effective avenue for the spread of weed seed. Water that ultimately ends up on a farm or ranch has normally traveled through miles of waterways, many of which traverse weed infested areas. Weed seeds vary greatly in size, shape, weight, and morphology (form and structure). One common feature shared by most weed seeds is that they float and are easily transported in water.

Some weed seeds, such as curly dock, have developed special morphological characteristics that improve their transport in rivers, streams, and irrigation canals. Researchers have demonstrated that many weed seeds, even without special adaptations, can stay afloat long enough to reach a farm or ranch in surface water (Wilson 1980; Radosevich and Holt 1984). A significant impact of water-transported weed seeds (primarily through irrigation
water) is the introduction of new species onto a farm or ranch. Once established, these new weeds can spread rapidly to become permanent fixtures in infested fields. Weed-seed contaminated water can also help replenish the soil seedbank. For local weed species that are already well-established in a field, a few extra weed seeds in the irrigation water will make little difference. Although thousands of weed seeds may be introduced through irrigation water annually, this number pales in comparison to the millions or perhaps even billions of seeds that already exist in the soil. Irrigation water filled with weed seeds rebuilds the soil seedbank and replaces weed seeds that have sprouted and been controlled as seedling weeds in the field. Therefore, weed control activities designed to reduce weed pressure become less effective over time as the seedbank in the soil is replenished despite control efforts.

**Strategies to prevent arrival of weeds by water:**

- Prevent weed seed production along the banks of irrigation canals and ditches with emphasis on late-season when weed seed production is at its peak.

- Prior to the first irrigation of the season, clean canals and ditches and allow winter debris and weed seed to be flushed from the system before turning water onto fields.

- Screen irrigation water to remove weed seeds before application.
1 Some weed seeds have developed special morphological characteristics that improve their transport in water. Curly dock seed is encased in a seed pod that allows it to float on the water surface. Note the growth of curly dock seedlings near the previous year’s water line in the dry irrigation ditch.

2 Regular weed management on canal banks and ditches, even cement-lined ditches, is necessary to prevent weeds from maturing and spreading seeds downstream.

3 A variety of options exist for screening irrigation water to remove weed seeds prior to use. These could include rotating, self-cleaning screens, in-stream screens, and bubblers. Note the yellow nutsedge seedlings that have germinated on the screen of the bubbler.
1 Some weeds have evolved through wind dispersal mechanisms such as a parachute-like pappus. Prickly lettuce, musk thistle, and yellow starthistle each have parachute-equipped seed that can be carried by wind currents.

2 One of the most successful weeds with wind-dispersed seed is horseweed. Horseweed seed has been collected in wind currents greater than 450 ft above the ground. At that height, the seed can travel over 100 miles in a single storm.

3 Weeds such as Russian thistle and kochia are known as tumbleweeds. When mature, these plants become globe shaped. During the winter, the upper part of the plant can break from the root and be blown by the wind. As these weeds tumble, seed is dispersed.

4 Tumbleweeds often collect along fences, windbreaks, in gullies, canals, and ditches. Burning or removing these accumulations can reduce the potential weed seed reservoir.

5 Weeds with wind-dispersed seed often grow on field edges and fence lines. Scouting fields and removing the potential for production of wind-blown weed seed will reduce future weed problems.
Many weeds use wind as a mechanism for seed spread. Extreme weather events such as hurricanes or tornadoes can move weeds and weed seeds great distances. Some weeds have evolved wind dispersal mechanisms such as a parachute-like pappus. Parachute equipped seed of weedy plants, like the common dandelion, can be carried even by mild wind currents. The majority of wind-blown seeds remain within a short distance of the parent plant. The most important factor that controls movement by wind is the size of the pappus relative to the size of the seed. Yellow starthistle has a small pappus attached to a large seed which permits seed movement only a few feet from the parent plant. Prickly lettuce, however, has an extensive pappus that enables its seed to move significant distances from the parent plant. Weeds with wind-dispersed seed often grow taller than surrounding plants. Seed produced on tall plants is more likely to be influenced by stronger wind currents. It has less probability of being intercepted by nearby plants than seed produced within the crop canopy.

Horseweed seed is wind-dispersed. It is a common weed of ditchbanks, fencelines, pastures, roadsides, and production fields across the U.S. Horseweed is a plant with a small seed size relative to its pappus and often grows above the canopy of nearby plants, which makes it a likely candidate for effective wind dispersal. Horseweed seed has been collected in wind currents at an elevation of over 450 ft above the ground (Shields et al. 2006) where prevailing winds can move the seed over 100 miles (Dauer et al. 2007).

Another way that wind can disperse weed seeds is by transporting entire plants. Weeds such as Russian thistle and kochia are known as tumbleweeds. These plants are globe-shaped and become stiff and dry late in the growing season. During the winter, the upper part of the plant can break away from the roots and be blown by the wind. As these weeds tumble, seed is dispersed. Individual tumbling Russian thistle plants have been estimated to move up to 2.5 miles (Stallings et al. 1995).

**Strategies to prevent arrival of weeds by wind:**

- Scout field and farm/ranch borders for weeds with wind-dispersed seed, particularly weeds that do not yet occur on the property.
- Control mature tumbleweeds by burning or removing those that have accumulated along fences, windbreaks, in gullies, canals, and ditches to reduce the potential weed seed reservoir.
WEED ARRIVAL BY ANIMALS AND HUMANS

All agricultural operations interact in some way with animals that have the potential to transport weed seed from one area to another. Livestock producers often shuttle animals in and out of the herd or rotate livestock from one pasture to another. Every operation is also affected in some way by wildlife (rodents, birds, deer, etc.) which often travel across different farms and ranches every day. Regardless of method, animals, both wild and domestic, can be an important source of weed seed movement onto farms and ranches.

There are two primary ways in which weed seeds are transported by animals: 1) attachment to the external surfaces of an animal’s body, and 2) consumption of weed seeds and subsequent deposition in manure. In either case, there is a period of time that can last anywhere from a few seconds to several days in which a weed seed can be transported by an animal. The distance weed seeds move with animals depends on the mechanism of attachment (internal or external), and the distance the animal travels.

Some weed seeds have thorns, spines, barbs, hooks, or bristles that readily stick to hair or other parts of an animal’s body. The seed of burdock, for example, contains many spines that are tipped with a tiny hook that adheres to animal hair. Even seeds without a special means of attachment can be transported by animals in mud or wet soil that adheres to hooves and fur.

Another way weeds can be spread by animals is through consuming feed contaminated by weed seed. In the days following consumption of contaminated feed, weed seeds make their way through the digestive tract, and many remain viable when deposited in the manure. As animals move from one location to another, or are moved into or out of pastures, large quantities of weed seeds can be spread wherever the manure is deposited. In the case of livestock transported via rail or truck or migrating birds and other wildlife, the dispersal of weed seeds can occur over long distances.

Humans can also be an important source of weed spread onto farms and ranches. Agricultural producers often visit other operations or host visits from an assortment of salesmen, consultants, friends, and other widely travelled individuals who can introduce new weeds. Weed seeds can adhere to shoes and clothing and may find their way into shoes, cuffs of pants, and pockets which can be effective weed seed transport mechanisms, regardless of seed shape or size (morphology).
Livestock have the capacity to transport weed seeds, internally and externally, as they are shuttled into or out of the herd or are rotated from one pasture to another. Other animals, companion animals, like cats, dogs, and horses, often travel to new areas beyond the borders of a farm or ranch and may be carrying weed seeds in fur, hide, or feces.

Weed management on every operation is affected by wildlife (rodents, birds, deer, etc.). These animals often travel through or over different farms and ranches every day. Wildlife can be an important source of introduced weed seed on farms and ranches.

Some weed seeds have special adaptations such as thorns, spines, barbs, hooks, or bristles that readily stick to hair or clothing. Houndstounge is a weed that commonly attaches to clothing and becomes tangled in fur/hair.
1 Even seeds without a special means of attachment can be transported by animals in mud, wet soil, or manure that adheres to hooves, fur, or tack.

2 Weeds can be spread by animals through consuming feed contaminated by weed seed. In the days following consumption of contaminated feed, weed seeds make their way through the digestive tract, and many remain viable when deposited in the manure. Note the dodder seedlings that have germinated in the cow manure.

3 Agricultural producers often visit other operations or host visits from an assortment of salesmen, consultants, friends, and other widely travelled individuals who can introduce new weeds on clothing, equipment, or boots.

Strategies to prevent arrival of weeds by animals and humans:

- Avoid livestock feed and bedding contaminated with weed seeds.
- Prevent animals from grazing in weed-infested pastures or rangeland when viable seeds are present.
- When weed-infested forage has been consumed, quarantine livestock by feeding clean forage for at least 4 to 7 days to allow the weed seed to pass before moving them to a new area.
- Clean mud and manure (both of which can contain weed seeds) from hooves and hair of livestock before moving from one location to another.
- Monitor areas frequented by wildlife (waterways, ponds, fence lines, field borders, wooded areas, etc.) for new weeds.
- Require visitors to clean shoes, pants and other clothing of mud and weed seeds.
Throughout history, humans have introduced plants into new areas for use as food, forage, fiber, medicinal, and ornamental uses. Introductions commonly occur without a complete knowledge of how aggressively plants will grow and reproduce in their new environment. Consequently, some of the most troublesome weeds in the West are an unintended result of intentional introductions. The new plants thrive in the absence of native pests and plant competitors, and are able to escape cultivation to invade farms, ranches and natural areas. Some examples of escaped intentionally introduced plants include purple loosestrife, goatsrue, and Russian olive.

**WEED ARRIVAL BY INTENTIONAL INTRODUCTION**

1. **Purple Loosestrife**, a native of Eurasia, was introduced into North America in the 1800s as an ornamental. An individual plant can produce up to 2.5 million seeds annually that are dispersed by wind, water, aquatic wildlife, and people. It invades wetlands, replaces native vegetation, has low feed value, reduces wildlife habitat, and clogs irrigation systems. Movement in the western states seems to be closely related to the development of irrigation systems (Thompson et al. 1987). It is currently found and listed as a noxious weed in all western states except Alaska and Hawaii. Despite its detrimental effects, purple loosestrife is still a popular ornamental plant.

2. **Goatsrue** is a native of Europe and Asia that was introduced into Cache County, Utah in 1891 as a potential new forage crop. Plants were inferior to alfalfa in yield and protein content, and were found to be unpalatable and toxic to livestock (Tingey 1971). Goatsrue escaped cultivation and, over the next 93 years, spread across northern Utah and into several other western states. It reproduces by large, heavy seeds, which are readily transported by irrigation water (Evans 1984). Goatsrue is on the Federal Noxious Weed List, along with the state lists of California, Nevada, Oregon, Washington, and Utah.

3. **Russian Olive** was introduced into North America from southern Europe and western Asia as an ornamental. It has been cultivated and widely used for shade trees, hedges, windbreaks, snowbreaks, soil stabilization, wildlife habitat, landscaping and to provide pollen for honeybees. Russian olive can grow on bare, mineral substrates and dominate riparian vegetation. It often grows in thickets, excluding other species and displacing native vegetation. Seeds can be distributed by animals, especially birds, and water. Growth along the banks of waterways depletes water resources, can restrict water flow, increase flooding and soil erosion (DiTomaso and Healy 2007).

**Strategies to prevent arrival of weeds by intentional introduction:**

- Research individual species and cultivars before selecting new plants for food, forage, fiber, medicinal, and ornamental plantings.
- Avoid introducing plant species that are listed on federal or state noxious weed lists.
Any material that is brought onto a farm or ranch has the potential to introduce weeds. Weeds, as seeds and plant parts (rhizomes, roots, stem tissue, stolons, and tubers), are spread in contaminated agricultural and building materials, such as seed, feed, bedding, and fill materials like topsoil, sand, and gravel. All agricultural products and construction materials should be stored in an area that is free of weeds.

Use clean agricultural seed. Ensure that seed has been properly cleaned before purchase. Gravel, sand, and soil have the potential to move large amounts of weed
seed and weedy plant parts as they are used for construction purposes or as fill for areas that will require some type of landscaping after construction. In many instances weeds have been introduced during ornamental landscaping activities through the introduction of contaminated bark, compost, nursery stock, sod, and in mulch derived from hay or straw.

Seed cleanings are often used as a cheap source of feed in order to augment the protein content of animal rations. Although cheap to purchase, seed screenings can contain large numbers of weed seed contaminants. Appropriately processed seed screenings can be safely used but care should be taken to monitor the grinding and heating processes used in preparation of the feed. Fresh or composted manure applied to fields should be monitored prior to purchase or application to ensure appropriate

1 Baled hay and straw can contain weeds and weed seeds that were incorporated into the bale at the time it was processed. Note weeds along alfalfa field border that could be part of the windrow and not easily seen in final baled product.

2 Contaminated seed, such as jointed goatgrass seed in wheat, is a common source of new weed introductions. Movement of contaminated seed from one area of the farm to another, or to another farm, results in the expansion of weed problems. Cleaning equipment between loads, crops, and fields can play a critical role in reducing the chance of weed introductions.

3 When construction or landscaping projects call for topsoil or gravel, it is appropriate to evaluate the source of the material. Bringing new soil onto a farm or ranch often means the introduction of new weed seeds coming in as part of the soil-seed reservoir. Examining the site from which the soil or gravel will come, if possible, is a proactive effort that could eliminate a serious problem for the future.
1 Manure or improperly cured compost can be the source of a large number of viable weed seeds. Most weed seeds can be killed if manure is composted by heating to greater than 140°F for a minimum of several hours. Failure to control weeds around storage areas can result in additional contamination of manure and compost by weed seed and other plant parts.

2 Weed seeds that are similar in size and shape, such as dodder in alfalfa, are difficult to prevent as a contaminant in poor quality seed. Note alfalfa infested with dodder from contaminated seed.

3 Few investments are more important than purchasing high quality seed. Certified seed guarantees the genetics, germination, and purity of the crop being planted and will provide insurance against introduction of new weeds through seed contamination.

processing and mortality of weed seeds and other weedy plant parts. Any container, plastic or fabric bag that has been used to transport seed should be considered a possible source of infestation and care should be taken to clean, sanitize, or destroy contaminated material.

Ultimately, legal measures are an important step in the management of weed spread by agricultural and building products. Seed laws, both state and federal, combined with weed laws in the development of quarantine requirements and seed certification guidelines are an important part of weed prevention in agricultural products.
Strategies to prevent arrival of weeds by contaminated agricultural and construction products:

- Use weed free seed, feed, bedding, and construction materials.
- Whenever possible, personally inspect production and storage areas of agricultural and construction products prior to purchase, to know what weeds may be contaminants.
- Store construction and agricultural materials in a weed-free area.
- Compost livestock manure contaminated with weed seed and monitor temperature (most effective 140°F), moisture content (high moisture best), and time (depends on weed species but should exceed several hours).
- Be aware of seed and weed laws designed to protect agricultural producers.
1 Puncturevine often grows in and around roadways, where it produces seed with stiff thorns that can penetrate and adhere to tires, thereby being easily moved to other locations.

2 Weeds that do not naturally spread far from the parent plant can be transported long distances with the help of vehicles and equipment. When vehicles pass through roads, pastures, field borders, and other areas with mature, seed-bearing weeds, those weeds can be spread from a few feet to hundreds of miles. Note the tumble mustard carcass caught in the grill of pickup truck.

3 Harvest and tillage equipment often comes into contact with mature weeds. Seed can collect on implements, which are then transported from field to field or farm to farm.

4 Mud and manure collected on or in vehicles and trailers can carry weed seed to distant locations. Weed contaminated soil-residues left on tillage equipment can be carried from field to field and farm to farm.

5 Maintain weed-free zones around regularly used roads, gates, facilities, and storage areas to reduce the possibility of seed accumulation on tires, surfaces of vehicles, and equipment.

WEED ARRIVAL BY VEHICLES AND EQUIPMENT

Modern agricultural operations host an assortment of vehicles and equipment every day. Equipment that is used outside the farm or ranch, whether through lease, loan, trade, purchase, or custom hire, has the potential to introduce new weeds. Similarly, vehicles used by farm or ranch visitors, such as salesmen, service providers, employees, neighbors, and family members, and those used to transport agricultural commodities, supplies, and livestock on or off the property can be the source of new weeds. Cleaning vehicles and equipment as they move from farm to farm or from field to field is a powerful tool for successful prevention.

Weeds that do not naturally spread far from the parent plant can be transported long distances with the help of vehicles and equipment. Some weeds, such as
puncturevine, have seed with stiff thorns that penetrate and adhere to tires. Seed of other weeds can be snagged and carried on the undercarriage of vehicles as they travel off-road. In either case, seed and other plant parts can adhere to the vehicle while it travels anywhere from a few feet to hundreds of miles.

Farm equipment, particularly that which is used for harvest, often comes into contact with mature weeds. Seed can collect on implement surfaces, which are then transported from field to field or farm to farm. Vehicles used to move agricultural commodities and construction materials, such as trucks and trailers, can harbor large quantities of weed seed when not cleaned after hauling contaminated loads.

Weed seeds and vegetative plant parts (rhizomes, roots, stem tissue, stolons, and tubers) often build up in the soil to create a large seed bank. Mud collected on tires and the undercarriage of vehicles can carry weed seed to distant locations. Soil disturbance activities, such as tillage, trenching, and planting, often leave soil residue on equipment that can introduce new weeds when used later at other locations. Trucks and trailers can become contaminated with mud and manure when hauling livestock and move seeds from one farm or ranch to another during loading and unloading.

Strategies to prevent arrival of weeds by vehicles and equipment:

- Clean farm or ranch vehicles and equipment that were used outside the property to remove accumulated plant and soil residue prior to return.
- When renting or purchasing used equipment or vehicles, sanitize before bringing them onto the farm.
- Perform cleaning operations in a designated area to make controlling new, emerging weed patches easier by limiting them to a specific, known location.
- Maintain weed-free zones around regularly used roads, gates, facilities, and storage areas to reduce the possibility of seed accumulation on tires and surfaces of vehicles and equipment.
- Avoid driving vehicles and equipment through weed infested areas during periods of seed production.
- In crop fields that will eventually be harvested, manage weeds with the goal of preventing seed production to limit contamination of harvest equipment.
- Ensure trucks and trailers are clean after hauling weed contaminated commodities, construction products, and livestock.
- Limit wheel traffic on the farm or ranch by visitors providing an alternate vehicle for use on the property.
Weed invasion can also occur when existing populations of weeds are modified by selecting a resistant biotype through repeated use of the same herbicide (i.e., invasion from within). Many farmers and ranchers in the U.S. rely heavily on herbicides as their primary weed management tool. Agricultural producers should be concerned about the development of herbicide-resistant weeds. When herbicides are repeatedly or improperly used, weeds can become resistant to the chemicals applied. Although resistant weeds could invade...
to a field with a weed population numbering in the thousands or millions, it is possible to select at least one plant that is naturally resistant to the herbicide. The resistant plant(s) survive and produce seed while susceptible plants are killed. Initially, resistant plants appear as isolated individuals or small patches. With repeated use of the herbicide, resistant plants spread rapidly and soon dominate the field, rendering further application of the herbicide useless.

If herbicide resistance has not yet impacted a farm or ranch, there is a good chance it will in the future. The first known case of herbicide resistance in the U.S. was common groundsel, which was reported resistant to simazine in Washington state in 1970 (Ryan 1970). Since then, resistance among weeds has grown rapidly to include 217 weed species with some plants resistant to all major herbicide families (Heap 2013). Without modifications in weed management practices, this trend will almost certainly continue. Producers select herbicides based on criteria such as performance, ease of use, cost, and environmental impact. When the herbicide of choice is no longer effective, a producer is forced to use a less desirable herbicide option. The number of new herbicides (novel active ingredients) entering the market continues to decline. The likelihood that a current active ingredient, lost to resistance, can simply be replaced by something newer in the developmental pipeline is diminishing.

Strategies to prevent development of herbicide resistant weeds:

- Use other weed control tactics (mowing, grazing, burning, biological control, tillage, crop rotation, row spacing, etc.) in combination with herbicides.
- Rotate herbicide families and avoid more than two consecutive applications with the same herbicide group.
- Scout fields regularly, apply herbicides at the proper rate and timing, and do not make unnecessary herbicide applications.
- Respond immediately to suspected cases of resistance by preventing seed production or seed movement.
1 Poor crop management practices reduce the vigor and competitive ability of field crops and forages and make them more susceptible to weed invasion. A drill malfunction in a dryland wheat planting (left image) shows the effect of no competitive crop on weed establishment in an area that became a haven for weed invasion. On the right, poor winter wheat emergence from dry fall conditions provided space for the poisonous weed halogeton to invade.

2 Establishing and maintaining a healthy crop, such as wheat and alfalfa, is a powerful tool to resist weed invasion. To promote a competitive crop, learn and implement best management practices for a particular field, crop, or forage.

3 Best management practices for pasture include seeding, fertilization, irrigation, etc., but must also consider livestock management.

When preventing the arrival of a new weed fails and contamination of the farm or ranch occurs, management efforts should be redirected (at least for the species in question) toward preventing establishment of the new invader. Preventing the establishment of new weeds on a farm or ranch implies an emphasis on early detection and rapid response, and management activities that favor desirable plants and suppress weed growth.

Establishing and maintaining competitive stands

Agricultural systems are comprised of a collection of decisions and inputs. Successful farmers and ranchers learn and implement best management practices (BMP) for every commodity produced. Weed control influences and is influenced by every component of a BMP program. The objective of a successful weed BMP is to establish and maintain a healthy crop that will resist invasion. Competitive stands (healthy crops) prevent weed
crop, use weed-free seed, plant when conditions favor crop growth, irrigate, fertilize, and harvest properly, and do not overgraze pastures. Seeding rates, row spacing, variety selection, and seeding depth can all influence the vigor of a new crop.

Planning ahead is the best way to have a competitive stand in place when potential weed introduction is possible. Grazing activities and seeding operations promote soil disturbance and are an opportune time for weed invasion. Less palatable weeds increase grazing pressure on desirable plants in pasture and rangeland and increase weed density and spread by animals. To promote a competitive field spread by out competing weed seedlings and preventing them from growing and maturing so they cannot reproduce from seed.

Strategies to prevent weed establishment by promoting competitive stands:

- Learn and use best management practices for every commodity produced.
- Plan ahead to allow for timely implementation of appropriate cropping practices.
Invasion by any new weed, such as hoary cress (pictured), begins with a single plant that grows to become a small patch and, eventually, an extensive infestation. If the problem is discovered early, it is easier to contain and manage than if it continues undiscovered and untreated for a long time.

Early detection of new species involves diligent monitoring. It is important to know which weeds are currently found on a farm or ranch (plant inventory) so that new or different species are obvious. Watch for plants that are out of place, specifically in areas more sensitive to invasion, such as: roadsides, irrigation ditches, waterways, animal feeding areas, or any area that has been recently disturbed. Some examples of potential weed invaders include buffalobur (top left), purple starthistle, black henbane, and yellow toadflax (bottom right).

Once a new plant has been detected, identification and assessment are the next steps. A good weed identification book, such as Weeds of the West, or a visit to your local county Extension Agent can be a valuable resource to determine the identity of a new species and to assess its potential to become a troublesome weed.

**EARLY DETECTION AND RAPID RESPONSE (EDRR)**

Weeds do not instantly dominate a farm or ranch. They start as individual plants that grow to become small patches and, eventually, extensive infestations. Early detection and rapidly responding to weed invasions is similar to obtaining preventative health care screenings from a physician. If the problem is discovered early, it is easier to contain and manage than if it continues undiscovered and untreated for a long time.

Early detection of new species involves diligent monitoring. It is important to know which weeds are currently found on a farm or ranch so that new or different species...
new species allows managers to evaluate its potential to become a troublesome weed. Assessment should include: size of infested area, growth stage of plant, seed production, site characteristics, and potential sensitivity of the invaded area that might limit control strategies (e.g., waterways) to allow for rapid development of the most appropriate response.

Once a weed has become established in an area, eradication is desirable. The goal is to kill all living parts of the new invader. If eradication is unreasonable, the objective should be to prevent seed production or reproduction by vegetative parts. Seeds can last for years in the soil. Even if a few weeds or a small patch is identified and controlled, regular and persistent reevaluation of the infested area is necessary for years to come.

**Strategies to prevent weed establishment through early detection and rapid response:**

- Scout fields and high-risk areas regularly for new weed species.
- Properly identify the plant, assessing its weedy potential and distribution.
- Immediately implement control strategies.
- Regularly monitor introduction sites.

are obvious. Watch for plants that are out of place, specifically in areas more sensitive to invasion, such as: roadsides, irrigation ditches, waterways, animal feeding areas, or any area that has been recently disturbed.

Once a new weed has been detected, identification and assessment are the next steps. Proper identification of a
Occasionally, new weeds become established in an area and the objective is to keep them from spreading. Successful weed management activities utilize the building blocks of integrated pest management (prevention and control techniques such as cultural, physical/mechanical, biological, chemical) and their application against undesirable vegetation.

Preventing the arrival of a weed fails and a new weedy species becomes established on the farm or ranch. In addition to a new species becoming established, fields and rangelands can change ownership or management. When new property is added, through lease or purchase, new weeds can become part of an existing weed management plan. Preventing the spread of new weeds from one location on the farm or ranch to another requires the consideration of preventing arrival and establishment, with special emphasis on containment and minimizing impact on already infested land.

Prevention of weed arrival and establishment dominates weed management activities on farms and ranches. The approach wildland firefighters use to contain a fire is a good model of how weeds can be contained. When trying to contain a fire there are two goals. The first is to stop it from spreading and the second is to put the fire out. These same strategies can be used to contain and attack weed infestations (Dewey 2003).
A perimeter, surrounding the core weed infestation, should be established to prevent it from spreading. Any small patches outside this perimeter should be intensively attacked. When the small patches are completely controlled, remaining resources should be redirected to the large concentration of weeds. Complete eradication may not be possible, but the core patch can be reduced and thus its negative effects mitigated.

Management of areas infested with weeds is intended to minimize weed impact on crop and livestock production.

Successful weed management activities utilize the building blocks of integrated pest management (prevention, cultural, physical/mechanical, biological, chemical) and their application against undesirable vegetation. Protecting the yield and quality of agricultural commodities by controlling weeds is an investment in the present crop and the future. Stopping seed production, reducing the seed-soil reservoir, and planting weed-free seed are management activities that increase economic return.

**Strategies to prevent weed spread through containment:**

- Scout frequently for new patches, particularly in areas highly sensitive to invasion.
- Sanitize equipment and vehicles and use weed-free seed.
- Stop or reduce weed seed production.
- Reduce travel through infested areas.
- Avoid leasing or purchasing land that is infested with weeds that have no reasonable management options.

**Strategies to prevent weed spread through management:**

- Plant competitive crop varieties using best management practices.
- Utilize cultivation and other tillage practices where appropriate.
- Investigate biological control (including grazing) as an option.
- Use chemicals according to label rates and timings and rotate active ingredient modes of action.
- Implement weed prevention techniques.
Weed prevention is an important part of protecting farms and ranches and is a piece of a much larger picture. Successful weed management, in the future, will require more emphasis on prevention.

Commonly heard is the term integrated pest management (IPM). IPM is comprised of management activities related to insects, diseases, and weeds. When the emphasis is primarily on weeds, it is sometimes referred to as integrated weed management (IWM). IWM is comprised of control strategies that include prevention, physical/mechanical, cultural, biological, and chemical. As components of IPM and IWM, prevention and preventive strategies are often overlooked or addressed only superficially.

When prevention is utilized as part of IWM it is comprised of three lines of defense against the invasion of new weeds: prevent arrival, prevent establishment, and prevent spread. Depending on the weed species and its situation (present or not yet present on the farm), farmers and ranchers may focus their efforts on preventing arrival, establishment, or spread, or any combination.

Whenever a new weed enters the biological system, it causes farm and ranch managers to spend more time and money on the weed management treadmill. No matter the initial cost, prevention is always the most economical approach to weed management.
REFERENCES


PHOTO CREDITS

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Pages 2-3. Man hoeing weeds, Shutterstock; Green foxtail and dandelion, Shutterstock; all other photos, Earl Creech, USU.

Pages 4-5. Transportation, Shutterstock; Russian knapweed infestation and flower, Nate Belliston, Uintah County Weed Department (UCWD); musk thistle patch, Nate Belliston, UCWD; jointed goatgrass infestation, USDA Archives, bugwood.org; buffalobur, Corey Ransom, USU; all other photos, Steve Dewey, USU.

Pages 8-9. Furrow irrigation, Felipe Barrios-Masias, University of California-Davis; Reservoir, Corey Ransom, USU; canal and river, Shutterstock; Russian olive, Ralph Whitesides, USU; purple loosestrife, Nate Belliston, UCWD; all other photos, Earl Creech, USU.

Pages 10-11. Curly dock seed, Ken Chamberlain, Ohio State University, bugwood.org; irrigation bubbler, Joel Felix, Oregon State University; all other photos, Earl Creech, USU.

Pages 12-13. Prickly lettuce seed, Corey Ransom, USU; yellow starthistle seed, Cindy Roche, bugwood.org; horseweed plant, Bruce Ackley, Ohio State University, bugwood.org; horseweed seed, D. Walters and C. Southwick, USDA, bugwood.org; kochia on field border, Leslie J. Mehrhoff, University of Connecticut, bugwood.org; tumbleweeds on fence, Brad Schultz, University of Nevada Cooperative Extension; all other photos, Earl Creech, USU.

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Pages 18-19. Jointed goatgrass in wheat, Steve Dewey, USU; soil in hand, Gary Neuenswander, USU; all other photos, Earl Creech, USU.

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Pages 28-29. Buffalobur and purple starthistle, Corey Ransom, USU; all other photos, Nate Belliston, UCWD.

Pages 30-31: Foxtail barley, Steve Dewey, USU; all other photos, Nate Belliston, UCWD.

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