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Ecology and Management of Invasive Hawkweeds [*Hieracium spp*]

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Figure 1. A large orange and yellow hawkweed infestation in a mountain meadow.

Abstract

The invasive hawkweeds (*Hieracium* spp; Asteraceae taxonomic family) are creeping perennial forbs with fibrous roots, creeping stolons, milky sap, and showy orange or yellow dandelion-like flowers (see Figure 1). There are four species known to grow in Montana; orange hawkweed (*Hieracium aurantiacum*) being the most common, infesting approximately 51,000 acres and meadow hawkweed (*H. caespitosum*; considered a complex of three highly hybridized species), also called yellow hawkweed, occupying an estimated 6,000 acres.

Native to Europe, orange hawkweed was introduced into the United States in the early 1800's as an ornamental due to its bright flashy flowers. Orange and meadow hawkweeds were first recorded in Montana from Flathead County in 1961 and 1993, respectively. As of 2007, 16 Montana counties, predominantly in the northwestern part of the state, had reported hawkweed infestations. They are listed as Category 2 noxious weeds, meaning they have been recently introduced into Montana and/or are rapidly spreading from current infestations. Management criteria for Category 2 weeds include awareness and education, prevention of movement into non-infested areas, monitoring and containment of known infestations, and eradication where possible.

Hawkweeds reproduce by seed and vegetatively by aboveground runners (stolons). Seeds are produced both sexually by pollination and asexually without pollination. Hawkweeds are very invasive due to their spread by seed initially and then local population expansion by stolons. Once established, hawkweed rosettes and seedlings can form a solid mat excluding desired species. Hawkweeds thrive on low productivity soils and are found in mountain meadows, deforested areas, high alpine hillsides, along roads and waterways, and in lawns.

Applications of nitrogen, phosphorous, and potassium fertilizer (300 pounds/acre 15:15:15) have been used to reduce hawkweed infestations on low productivity sites by increasing the competitiveness of desirable plants. Growth regulating herbicides such as 2,4-D, aminopyralid, clopyralid, and picloram can provide short-term control when applied in the spring or early summer. Surfactants in the spray solution will improve herbicide contact with the hairy stems and leaves and increase herbicide efficacy. Hawkweeds are excellent candidates for integrated weed management using combinations of fertilizer, herbicide, and seeding competitive plants. Sheep and rabbits eat the flowers of hawkweeds but have little impact on populations, and are more likely to utilize perennial grasses reducing their competitiveness with hawkweeds.

Biology and Ecology

Taxonomy. *Hieracium* is a large genus with about 260 plant species native to Europe and approximately 25 species native to North America. Twenty-one non-native *Hieracium* species are known to occur in North America, four of which have been found in Montana. They are *H. aurantiacum* (orange hawkweed), *H. caespitosum* (=*Hieracium pratense*, meadow hawkweed), *H. floribundum* (yellow devil hawkweed), and *H. piloselloides* (tall hawkweed). The latter three species all have yellow flowers and are hard to distinguish from each other due to hybridization. As of 2006, only *H. aurantiacum* has been reported in Wyoming. *Hieracium* is from the Greek root *hierac*, "a hawk". The ancient Greeks attributed the keen eyesight of hawks to their eating the milky sap of *Hieracium* species. Other common names include devil's paintbrush, fox and cubs, king devil, and missionary weed.

Hawkweed species interbreed freely and have long been known for their complex, convoluted, and confusing classification. Detailed descriptions of *Hieracium pilosella* have listed 624 subspecies. Historically, *Hieracium* is one of the genera Gregor Mendel used to verify the laws of inheritance he developed from crossing varieties of pea plants (*Pisum*). Unfortunately for Mendel, all his painstaking emasculations and crossing experiments on *Hieracium* species he used led to results in direct contradiction to his laws because of the apomictic development of seeds. Embryos of *Hieracium* developed into seeds without pollen fertilization (parthenogenesis) and resulting plants were clones of the mother plant and not the combination of DNA from pollen and ovule.

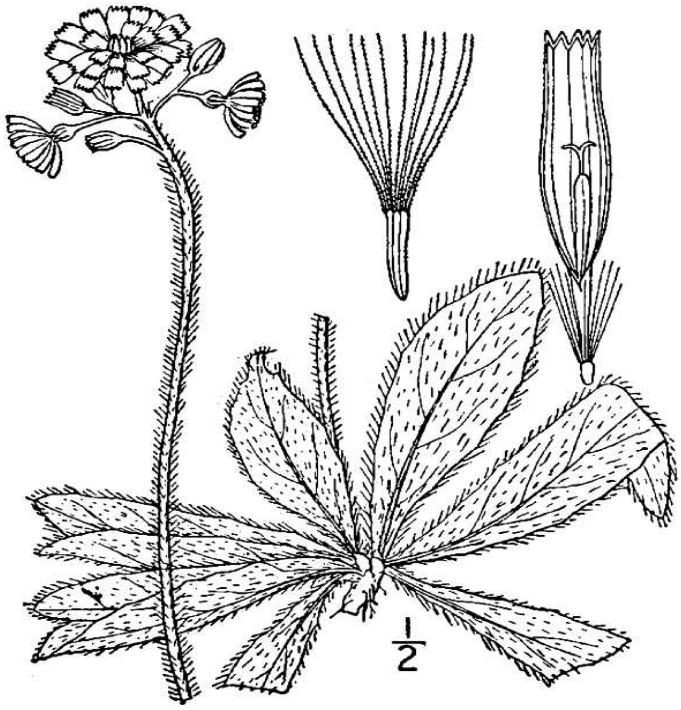

Figure 2. Orange hawkweed scape, rosette, and seed schematic.

Identification. The invasive hawkweeds are creeping perennial forbs with fibrous roots and milky sap. They produce basal rosettes with persistent narrow leaves four to six inches (10 to 15 cm) long (see Figure 2). The dorsal leaf surface is dark green, the ventral leaf surface is light green, and the margins are entire or minutely toothed. Orange hawkweed leaves are bristly with short hairs and meadow hawkweed leaves are smooth. The leaves are broadest near the tip tapering to a somewhat pointed base - oblanceolate (see Figure 2). Up to 30 flowering stems with short stiff and stellate (branched, or star-shaped) hairs can grow from each rosette. Flowering stems can be leafless, or there can be one to three clasping leaves alternately arranged on the lower half of the flowering stems, the upper leaves smaller than the lower leaves. Each stem terminates with one to 50 bright orange (orange hawkweed) or yellow (meadow hawkweed) dandelion-like flower heads arranged in umbelliform (where there are many flower heads) inflorescences (see Figure 2). There are 12 to 30 ray-like (ligulate) flowers per head that produce columnar seeds with a tufted, tawny papus of persistent bristles on the flattened end of the seed. Up to 12 leafy, creeping aboveground stems (stolons) grow four to 12 inches (10 to 30 cm) from the flowering plants and can establish new rosettes (similar to strawberry plants).

Native *Hieracium* species can be distinguished from the non-indigenous hawkweeds by their leafy-branched flowering stems, absence of stolons, and flower heads arranged in open panicles. *Hieracium canadense* (*=H. umbellatum*, Canadian hawkweed), reported from north and central Montana, is yellow flowered and has small and early deciduous basal leaves. The leaves along the flowering stem are larger in the middle of the stem and reduced above. *Hieracium albiflorum* (white hawkweed), reported from western and central Montana, has white flowers. *Hieracium gracile* (slender hawkweed), reported from west and central Montana, has yellow

flowers but the rosette leaves are hairless and less than four inches long (<10 cm). *Hieracium albertinum, H. scouleri,* and *H. cynoglossoides* all have long hairs on the leaves and flowering stems. None of the native hawkweeds are considered invasive.

Roots. The hawkweeds have shallow, fibrous rooting systems. Rooting depth ranges from 1.5 to 4.5 inches (4-14 cm) and roots spread only about 4 inches (10 cm) on average with only a few small branches, many with no root hairs. Mycorrhizal associations (symbiotic fungi) have been reported from populations in Europe with up to 92% vesicular-arbuscular mycorrhiza infection in roots of *Hieracium pilosella*. In this association, the fungi gain sugars from the plants and the plants gain soil nutrients from the fungi. Radio labeled carbon studies showed a significant transfer of ^{14}C from *Festuca ovina* to *H. pilosella via* mycorrhiza.

Meadow hawkweeds also grow shallow rhizomes from axillary buds at the base of rosettes, and new rosettes can grow from adventitious buds located on the fibrous roots. Underground rhizomes and adventitious buds also serve as over-winter structures from which plants re-grow each year.

The phytotoxic chemicals chlorogenic acid, caffeic acid, umbelliferone, and apigenin-glucoside have been isolated from the roots of hawkweeds and are exuded into the soil by hawkweed plants. These chemicals may suppress the growth of competing plants, and may be antibacterial. Antibacterial effects of extracts of *H. pilosella* have been used as an antibiotic against brucellosis.

Rosettes. Rosettes are the vegetative phase of hawkweed populations and consist of five to eight low-lying hairy basal leaves. Among other functions, the hairs on the leaves prevent desiccation and herbicide uptake. Rosette leaves begin growth in April and usually grow upward at an angle to the ground except when growing under grazing pressure or harsh conditions, when they lie flat on the ground (see Figure 3). Rosettes form from seed, and from buds on stolons (orange and meadow hawkweeds), rhizomes, and roots (in the case of meadow hawkweed). In dense patches, rosettes tend to produce stolons in the middle of the patch and flowering stems on the perimeters. Under ideal conditions, one orange hawkweed plant can spread by stolons and infest an area two to three feet in diameter in its first year of growth. Rosettes are intolerant of shading by competitor plants. Hawkweed rosettes contain a number of phenolic chemicals with phytotoxic properties, including chlorogenic acid, caffeic acid, and umbelliferone, in the green leaves and in water extracts of dead leaves. Leachate extracted from hawkweed leaves suppress the germination and growth of some plants.

Figure 3. Hawkweed rosettes form early in spring.

Flowers. The initiation of flowering begins in late May and peaks in mid-June. A second flowering period in September has been reported. Hawkweed rosettes are monocarpic perennials. They can survive many years (half-lives of up to nine years) but die within a few months after flowering. A single rosette is capable of producing up to 30 flowering stems. Often the stems are bare of leaves although they may have one to three small clasping leaves. The stems are one to 36 inches tall and can produce up to 50 flower heads. The stems have black hair all along them and produce a milky sap.

Each flower head ranges from one-half to three-quarters of an inch in diameter, and consists of many tiny orange florets, each capable of producing one seed (see Figure 4). Flowers open in bright sun and are pollinated by a number of insects including bees, flies, moths, butterflies, and beetles. Although pollen of an individual floret develops before the style is receptive, self pollination is facilitated at the end of floral development when the stigmata recurves and contacts their own pollen-coated style. This increases pollination either by insect or by self pollination. In addition, Hawkweed plants can produce seeds without pollination. Each flower head can produce between 12 and 30 seeds.

Figure 4. Hawkweed flowers showing vibrant color and square petals.

Seeds. The seed of Hawkweeds is an achene. Seed production can be as high as 13,000 achenes/m^2 in ungrazed grasslands and 500 achenes/m^2 under moderate grazing by rabbits. Intensive grazing can prevent all seed production. The seeds are black and have a pappus attached to one end that facilitates wind dispersal (see Figure 5). In addition, each seed is ribbed, and the ribs have minute barbs that enable them to stick to hair, fur, clothing and vehicles. Seeds can be dispersed by wind, water, or "hitch-hiking", and are often moved in contaminated soil associated with transplanting new plants into gardens and flowerbeds. Seeds remain viable in soil for up to seven years and can germinate as soon as they are released from the parent plant.

Figure 5: Orange hawkweed seeds with papus that aids wind dispersal.

Most (99%) of new plants in a population are derived from vegetative reproduction rather than from seeds. Also, most seeds (80%) are dispersed within a population colony and less than 1% is found at a distance farther than 30 feet (10 m) from the parent patch regardless of the papus that aids in wind dispersal. Ninety percent of seeds are produced along the periphery of a hawkweed patch.

Many newly shed achenes germinate readily but there is some evidence of dormancy. Storage of achenes at 41°F (5°C) for 3, 6, and 12 months increased germination from 47 to 83, 72, and 81% respectively. Seeds had 25% germination after storage at 72 °F (22 °C) for six years.

Life history. The hawkweeds have four general life history stages: seeds, seedlings, rosettes, and flowering plants. The seed stage is important for establishment of new populations at long distances from the parent population and regeneration of the population after an event that kills the parent population, like an herbicide application. The seed stage is adapted to survive long periods of time and harsh conditions.

The seedling stage is the most vulnerable life history stage. In New Zealand, distinct flushes of germination occurred at the end of five to eight day moisture intervals, but seedlings only survived a few weeks. Experiments show seedling emergence is greatest in September and July and tends to follow soil disturbance in summer or early autumn. Seedlings that germinated in the summer grew quickly and reached adult size in eight to ten weeks. Most seedlings that germinate outside the parent colony die of desiccation or winterkill. Of 1,500 *H. Pilosella* seedling sown in July in experimental plots in Nova Scotia, 102 seedlings were recorded but only 18 were well established by October, the rest were killed by drought, high temperatures, and browsing. Over-wintering rosettes can be produced in as little as 47 days after germination. Only about 1% of rosettes in a colony are derived from seed, the rest are derived from stolons. Seedlings that germinate in the spring are most likely to survive and transition to rosettes.

Hawkweed populations are made up mostly of rosettes with densities of up to 3,200 plants per square yard (3,500/m^2). Population expansion within established patches is predominantly vegetatively from stolons or rhizomes that initiate from rosettes. The transition from the rosette

stage to the flowering stage is density dependent. Most flowering plants develop at the edge of a patch where rosette densities are lower than at the center of the patch where densities are greatest.

Hawkweeds are capable completing their lifecycles quickly. Seedlings emerging in March can produce flowers by mid-June and viable seeds by early August. As perennial hemicryptophytes, hawkweeds have their over-wintering buds at the soil surface.

Spread. Patch expansion of hawkweeds is primarily *via* stolons or rhizomes. Long-distance spread is primarily via seeds that can be carried by the wind, water, on the fur or in the gut of wildlife and livestock, and in soil. Seedlings have been reported in the excreta of birds. The buoyancy of the achenes in water is less than 18 hours. The rhizomes and stolons are spread during cultivation and under intensive grazing. Hawkweeds were first cultivated in the United States as garden plants because of their bright flowers. Hawkweed seeds are still marketed in flower packets and sold as garden flowers.

Habitat. Meadow hawkweed is a regular component of the native flora of the foothills of northern, central, and eastern Europe. Orange hawkweed originates from mountainous meadows and hillsides of northern and central Europe, and is cultivated elsewhere. The sub-arctic, temperate, and montane distribution of mouse-eared hawkweed indicates intolerance of high temperatures. In England, hawkweeds thrive in areas of low rainfall, dry over-grazed pastures, and steep slopes, and are seldom found in shaded habitats. In Europe they are mostly found in small patches in disturbed areas, and are considered ruderal species of pastures, roadside cutbanks, and meadows. Sites most susceptible to invasion are roadsides, moist mountain meadows, forest meadows and clearings, permanent pastures, hayfields, cleared timber units, and abandoned farmland. Soils that are well-drained, coarse-textured, and moderately low in organic matter are most likely to support hawkweeds, but they can tolerate a full range of conditions from gravelly to acidic soils, full sun to partial shade, and frost and snow cover. Hawkweeds are found in habitats that support oxeye daisy (*Chrysanthemum leucanthemum*), sulfur cinquefoil (*Pontenilla recta*), spotted knapweed (*Centaurea bieberstenii*), grey goldenrod (*Sloidago nemoralis*), wild carrot (*Daucus carota*), and dandelion (*Taraxicum spp*.).

Economic Impacts. Hawkweeds can form dense mats and choke out all other native vegetation in wildland settings. They cannot compete with crops due to herbicide use and many crops have a higher competitive ability. Hawkweeds are palatable species, fairly high in nutrients, so many grazing animals will eat them. However, they can become mono-cultures and choke out other desirable forage species. Infestations can spread to threaten lawns and gardens.

Management Alternatives

Fertilizer. Fertilization generally increases the growth and reproduction of noxious weeds. This is not the case for hawkweeds when they are growing with other plants because hawkweeds are adapted to nutrient poor soils. One study done in England found nutrient addition reduced hawkweed populations over three years in plots grazed by rabbits and plots protected from grazing. The study ranked the severity of the decline according to the nutrient combinations added as: +N < +NK < +NP < +NPK. The decline was more rapid and greater where grazing was excluded because rabbits also impacted the perennial grasses. There were increases in perennial grass dry weight production where nutrients were added in the absence of rabbit

herbivory. It is believed that fertilization reduced hawkweed populations in response to increased competition from perennial grasses and forbs. Annual fertilizer applications of 300 pounds/acre nitrogen, phosphorous, and potassium (15:15:15) are recommended to reduce hawkweed populations where competitive plants are growing with hawkweeds. On rangelands where other weeds that increase under fertilization are present, control measures to reduce these weeds should be applied before fertilization.

Herbicides.[1/] The hawkweed populations can be temporarily suppressed using phenoxy-type herbicides such as 2,4-D, aminopyralid, clopyralid, dicamba, and picloram. Application of 2,4-D is most effective at 1.5 to 2 quarts per acre (1.5-2 pounds active ingredient/acre) early in the growing season when hawkweeds are in the rosette stage of growth. Aminopyralid is effective when applied at 4 to 6 ounces/acre (Milestone®) to plants in the bolting stage of development. Clopyralid applied at 1.5 pints/acre (Transline® 0.5 lb a.i./acre) and picloram applied at 1 to 2 pints/acre (Tordon®) can suppress hawkweeds for up to six years. Dicamba at 2 quarts/acre (Clarity®) provides good control when applied to rosettes. Glyphosate applied at 2 quarts/acre will control hawkweeds where re-vegetation is planned. Addition of a surfactant in the spray solution will raise the efficacy of all herbicides by increasing adherence to the hairy stems and leaves of hawkweed.

Tillage. Hawkweed is not problematic in cultivated fields because crop competition and herbicidal control of weeds prevents its invasion in these areas. However, tillage alone will spread stolons and rhizomes and should be combined with crop rotation, nutrient management, and pest control practices. Tillage equipment used on sites with hawkweeds should be cleaned before use on weed-free areas to prevent weed spread.

Hand Pulling. Because hawkweeds have their perennial buds at the soil surface, hand pulling may be effective if rosettes and stolons are removed. Hand pulling may be practical where it can be repeated often on small patches, where there are competitive desirable plants in the community, and when combined with fertilization.

Mowing and Grazing. Mowing hawkweed is ineffective for reducing populations because the low-lying rosettes, stolons, and rhizomes grow below most mower blade height settings. Mowing infestations when plants bolt to produce flowers will prevent seed production but may encourage vegetative spread. Grazing animals eat the flower heads of hawkweed, but the rosettes are not usually eaten. Therefore, grazing may have a similar effect on hawkweed populations as mowing. The disturbance associated with grazing may help spread hawkweeds. In fertilizer experiments, the decline of hawkweed in fertilized plots was greater where grazing was excluded than in plots that were grazed. Prescribed grazing to maintain grass vigor will help prevent hawkweed invasion and spread. Over-grazing can make areas more susceptible to invasion.

[1/] Any mention of products in this publication does not constitute a recommendation by the NRCS. It is a violation of Federal law to use herbicides in a manner inconsistent with their labeling.

Biological Control. As of 2007, no insect species have been approved for release in the United States for control of orange or meadow hawkweeds. Host specificity testing has been conducted for five insect species. Two of these species have been dropped from consideration, testing continues for two of the species, and testing has been completed for the hawkweed gall wasp (*Aulacidea subterminalis*). Results indicate it is sufficiently host-specific for field release. Several other insects are being considered. In addition to the insects, two fungi are being tested in New Zealand.

Animal feeders of hawkweeds include nematodes (*Tylenchus heiracii*), Hemiptera (true bugs), Lepidoptera (caterpillars), Hymenoptera (ants, wasps, and bees), rabbits, and sheep. Parasites include basidiomycete and deuteromycete fungi.

Re-vegetation. Re-vegetation is an important management practice on disturbed sites under the threat of invasion by hawkweed, such as forest clearings and overgrazed meadows, and where dense populations of hawkweed have excluded competitive desirable plants. The development of a shading canopy is important to sustainable management of hawkweeds because hawkweeds are not shade tolerant. Shade from plant litter buildup will also reduce the competitiveness of hawkweeds. Seeding of competitive plants should be combined with herbicide application to reduce the competitiveness of hawkweed during establishment of the desirable plants, and fertilizer should be included to increase the competitiveness of desirable seeded plants.

Species selected for re-vegetating disturbed sites and hawkweed infestations should be appropriate for management objectives, adapted to site conditions, and competitive with the weed. Management objectives will determine if introduced or native species are seeded and the combination of species in the seed mix. The environmental conditions of the site including precipitation, soil texture and depth, slope and aspect, will affect species establishment. Refer to Montana Plant Materials Technical Note 46, 'Seeding Rates and Recommended Cultivars,' and Extension Bulletin EB19 'Dryland Pasture Species for Montana and Wyoming' for seeding rate guidance and re-vegetation species selection. State and area resource specialists can help determine the most appropriate, site-specific species mix and timing of seeding.

Integrated Pest Management. Integrated pest management is the application of two or more management alternatives so they are complimentary in weed suppression, increase the longevity of control procedures, and improve crop production, or conservation of resources. Fundamental to any integrated management of hawkweeds is competitive desirable plants. On small hawkweed populations, aggressive herbicidal control should be combined with cultural practices that strengthen the competitiveness of the plant community. In areas with large scale infestations, herbicides should be used to eradicate small satellite populations and to reduce spread along the invasion front of the parent population. Annual fertilization can be used to reduce the parent population over time where competitive plants are present. On disturbed sites, pastures, and rangeland where competitive plants have been lost, re-vegetation following herbicidal control of hawkweeds and fertilization will improve the longevity of the control application. On crop and hay land in rotation, tillage followed by herbicide treatment of regenerating hawkweed plants will be more effective than either treatment applied alone.

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