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Ecology and Management of Dyer's Woad [*Isatis tinctoria* L.]

by

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Figure 1. A flowering dyer's woad plant.

Abstract

Dyer's woad (see Figure 1) is a tap-rooted biennial weed threatening rangelands, forests, and pastures in Montana because of its rapid growth rate and prolific seed production. It is in the Brassicaceae (mustard) taxonomic family. Extensive infestations occur in northern Utah, southern Idaho, and western Wyoming. The maintenance and spread of dyer's woad populations are seed dependent and individual plants can produce on average 350 to 500 seeds. Plants are monocarpic, meaning they die after producing seed. Seeds can be transported by automobiles, rail cars, recreationalists and animals. The spread of dyer's woad on rangeland in the Pacific

Northwest was estimated at 14 percent per year and the reduction in cattle grazing capacity on infested land averaged 38 percent.

Dyer's woad is native to Eurasia. It has a long history as a medicinal plant and is cultivated as a dye crop. The first record of dyer's woad in Montana is from Missoula County in 1934 near the University of Montana pharmaceutical garden and by 2006 it had been reported from 12 Montana counties (http://invader.dbs.umt.edu). In Montana it has been found along roadways, railroads, recreation trails, creeks, and on rangeland. Currently, there is a program in Montana to contain and locally eradicate dyer's woad infestations.

Large tracts of land have been effectively managed by well organized large groups hand pulling dyer's woad. Metsulfuron applied up to the late bloom stage is the most effective herbicide treatment on pastures and rangeland and 2,4-D is effective when applied to rosettes. *Puccinia thlaspeos*, a native rust pathogen, has shown promise as a biological control of dyer's woad. On cropland, dyer's woad can be controlled by crop rotation, tilling, and herbicides. The Montana Dyer's Woad Cooperative Project started in 1984, has reduced the number of counties with dyer's woad from 13 to four, and the number of acres infested from 480 to 6.4, and is a good example of a successful noxious weed containment and eradication program. Largely due to the coordinated efforts of this project, dyer's woad has been downgraded from a Category 2 to a Category 3 noxious weed in Montana.

Biology and Identification

Life History. Dyer's woad is a biennial. It typically germinates from seed in the spring, produces a rosette during its first growing season, overwinters *via* dormant buds on the root crown, flowers, produces seed and dies in the spring usually during the second growing season after a vernalization period. Where environmental conditions are not favorable for seed production during the second growing season, dyer's woad can persist, forming rosettes for more than two years similar to a monocarpic perennial. Plants that persist for two years tend to form larger rosettes, flowering stems, and more seeds than plants that complete their life cycle in two years. However, plants die after seed production. It has also been observed as a winter annual, germinating from seed in the fall and producing seed the following spring. Flowering and seed production occurs only after a winter vernalization period.

Figure 2. The mature fruits of dyer's woad are dark blue or black and hang down from the stem on short, hooked pedicels.

Fruits and Seeds. Dyer's woad population persistence and spread is dependent on seeds. Clonal growth has been observed but it is not common. Seeds form in large fruits (technically silicles, see Figure 2) characteristic to dyer's woad and help identify the species. The fruits are flattened, winged, longer than wide, one-half to three-quarters of an inch long and about one-quarter of an inch wide (12 to 18 by 5 to 7 mm). They are also wider at the tip than the base (oblong to oblanceolate), and green when they first form turning deep blue to black at maturity. Mature fruits are pendulous from the inflorescence on a short stalk. The fruits remain intact (indehiscent) containing the seed after maturity. A chemical in the fruit inhibits germination and seedling growth of dyer's woad, other mustard species, and some other grass and forb species. The chemical is water soluble, will leach from the fruit over time, and may be allelopathically active in the soil.

Each fruit normally produces one viable seed. Seeds are brownish-yellow, cylindrical and weigh 3.9 mg. They germinate at temperatures ranging from 37 to 77° F (3 to 25°C). In a germination study, 100 percent of seeds threshed from the fruits germinated compared to 12 percent or less germination of seeds contained in the fruits. Seedling growth of germinants from seeds contained in fruits was also less than seeds from threshed fruits. Liquid from soaked fruits also inhibited germination and seedling growth. The auto-toxic chemical in the fruit may explain why more dyer's woad plants germinate in the spring after the chemical has been leached from the fruit, than germinate in the fall.

Dyer's woad seeds are generally short lived, however when intact fruits are buried in the soil, the seeds can remain viable for many years. Dyer's woad plants have been observed in plowed fields that had not been cultivated or supported dyer's woad for over ten years.

Roots. The thick, fleshy tap root of dyer's woad penetrates down to three feet (1.0 m) into the soil. Lateral roots grow in the upper foot (30 cm) of the soil profile. Lateral root branching is more predominant in the second growth season. The combination of tap root and lateral roots

help dyer's woad compete with annual and perennial plants for limited soil moisture, particularly in the fall and spring when soil moisture is greatest in semi-arid steppe regions.

Figure 3. A dyer's woad rosette showing the oblanceolate leaves with prominent cream colored mid-rib.

Leaves. Rosette leaves (see Figure 3) and stem leaves (see Figure 4) of dyer's woad differ slightly in morphology. Rosette leaves (basal leaves) grow up to seven inches (18 cm) long, are broadest near the tip and taper to a point at the base, have small-rounded teeth (crenulate), are ciliate and pubescent with simple hairs, and have a short petiole. Stem leaves have no petiole (sessile), have auricles that clasp the stem, the margins are mostly entire, and they are without hairs (glabrous). Stem leaves are alternate along the stem. All leaves have a prominent cream colored mid-rib extending the entire length of the leaf, and a blueish-green color. The leaf color and prominent mid-rib are good identifying characteristics of dyer's woad.

Figure 4. A dyer's woad stem showing sessile leaves with auricles that clasp the stem.

Leaf growth and rosette formation begins in the spring within one week of snowmelt, in many areas about the middle of April. Stem growth and inflorescence formation begins about two weeks later. The rapid spring growth rate and floral development help dyer's woad compete in semi-arid steppe regions where soil moisture is most abundant at that time. Natural rosette mortality is greatest between mid-June and mid-September during periods of low precipitation and high temperatures. In a Utah study, only 23 percent of young rosettes survived to mature rosettes, whereas 81 percent of mature rosettes survived to flower, and all flowering plants set seed. This suggests that control of dyer's woad will be most efficient when applied to mature rosettes and flowering plants particularly when labor-intensive hand pulling is used.

Figure 5. Dyer's woad flowering stems with yellow flowers and green silicles.

Flowers. The flowers of dyer's woad are bright yellow (see Figure 5). Like all mustard flowers, they have four sepals (about 0.14 inches or 3.5 mm long), four petals, six stamens; two of which are shorter than the other four (tetradynamous). There are many flowers on much-compounded racemes that reach one to three feet (0.3 to 1.0 m) in height. Multiple floral stems per plant is common for dyer's woad, and the combination of multiple stems with many branches bearing many bright yellow flowers gives dyer's woad plants a showy appearance. The length of time from the initiation of flower stem growth to seed set is about eight weeks.

Spread. Dyer's woad populations spread by seed. A Utah dispersal study found that most of the seeds were shed from plants within ten days from maturity and 95 percent of seeds were found within two feet of the parent plant. The winged fruit aids wind dispersal, however wind dispersal is believed to be short distance. Some seeds remain on the stem over winter and seeds may blow long distances on snow surfaces. Fruits also float and may be dispersed along waterways. Fruits may be transported by animals when they attach to their fur or pass through their digestive systems. Dyer's woad is also spread as a contaminant of hay and crop seed.

Habitat. Dyer's woad is native to the steppe and desert regions of the Caucasus, central Asia, and eastern Siberia making it pre-adapted to the steppe regions of the Great Basin in North America. It does well on rocky soil with limited water-holding capacity and it is commonly found in rugged, inaccessible terrain. It has low nitrogen requirements enabling it to persist under stressed, nutrient-poor conditions. It can invade on well-maintained rangeland with relatively little disturbance, however competitive desired plants will retard the spread of dyer's woad.

Economic Impacts. Historically, dyer's woad was the main source of blue dye in Europe until indigo was imported from the East Indies in the 1600's. It was also used as a tattoo ink. In the time of Julius Caesar, the Britanni dyed their bodies with pigment from dyer's woad to make them look terrifying in battle, and the Picts went into battle naked except for decorations made from dyer's woad war paint. Dyer's woad has been used as an astringent and the root is used in

traditional Chinese medicine to treat mumps, throat ailments, hepatitis, headache, and fever. The leaves of dyer's woad have 20 times more of the cancer preventing glucobrassisin than broccoli.

Currently, where dyer's woad infests rangeland in the Pacific Northwest, it has been estimated that cattle grazing capacity decreases on average by 38 percent. In Utah, reduced crop and rangeland production attributed to dyer's woad was estimated to be $2 million in 1981.

Management Alternatives

Hand Pulling. Hand pulling, hoeing and digging (rouging) have been used to reduce populations of dyer's woad on infestations that cover areas as large as 62 acres (25 hectares). For hand pulling to be effective, the first treatment should be applied when the dyer's woad population is approaching full bloom. The treatment should be repeated three to four weeks later to eliminate any plants that re-grew after the first treatment, or were missed during the first treatment. The tap root with the root crown must be removed or the plant will re-grow. Using a shovel to pry-up the tap root may help remove the root crown. Any pods formed on the plants should be stripped and disposed in a landfill or burned. In Utah, crews of volunteers pulled and rouged dyer's woad as described above on 17, 52, and 62 acre (7, 21, and 25 hectare) infestations over an eight-year period. After eight years, the amount of time required to pull all dyer's woad plants on the same number of acres was 90 percent less than the first year and the number of dyer's woad plants present were visually estimated to be 95 percent less than the first year. The study also found that seeds collected from pulled dyer's woad plants with green pods were capable of germination.

Herbicide.[1/] Metsulfuron (0.75 oz/acre) or chlorsulfuron (1.0 oz./ac.) and these herbicides combined with 2,4-D (3 pt./ac.) are the most effective herbicide treatments for controlling dyer's woad. A nonionic surfactant is needed when using chlorsulfuron or metsulfuron. Applying these herbicides or herbicide mixtures to rosettes and stems up to the late bloom stage prevents seed set and viable seed production, and targets first year rosettes. A 2,4-D only application can be made to dyer's woad rosettes, however when applied to plants that have begun to flower may not prevent seed set. Imazapic (8-12 oz./ac.) with methylated seed oil (MSO 1 qt./ac.) when applied to rosettes or bolting plants will also control dyer's woad. If spot treating an area with dyer's woad, flowering or seed-producing stalks can be removed and the basal leaves sprayed.

Grazing and Mowing. A study in Utah found that sheep ate about 16 percent of the dyer's woad plants on a rangeland site and consumed about 39 percent of the leaves on the rosettes up to May 18. After May 18, the sheep selected other plant species. In a concurrent clipping study, the researchers found that three clippings of 60 percent or two clippings of 90 percent of the leaf mass (dyer's woad plants were allowed to re-grow for two weeks between clippings) increased plant mortality and reduced seed production. They also found that a single 90 percent defoliation after May 23 had the same effect as the multiple clippings. They concluded that although sheep will use dyer's woad, the timing and intensity of the grazing would not reduce population fitness and may result in greater impact to desirable plants. If mowing dyer's woad it is recommended to apply the treatment during flowering but before the formation of more than 75 percent of the seed pods. This will prevent seed production and may increase mortality.

[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. *Puccinia thlaspeos* is a native rust pathogen that infects dyer's woad and prevents seed production. First found in southern Idaho in 1978, *P. thlaspeos* has spread to most dyer's woad populations in northern Utah. Inoculation of dyer's woad plants is most successful when either fresh or dried inoculum dosages of greater than 1.0 mg/plant containing teilosori are applied in the spring. Incidence of infection after inoculation in one study was 58 to 76 percent of the test rosettes compared to two to seven percent natural infection. The rust can be maintained naturally in the dyer's woad population for three years. One study testing the effects of herbicides on the viability of the rust found chlorsulfuron (up to 2.0 oz./ac.) and metsulfuron (up to 1.5 oz./ac.) did not affect teliospore germination of a *P. thlaspeos* culture, but 2,4-D (as low as 1 qt./ac.) and some brands of surfactant (0.25 percent by volume) did reduce teliospore viability.

Cropland Management. In annual crops and row crops, tillage can be used to reduce dyer's woad. Spring cultivation will kill vernalized rosettes and stop seed production. Seedlings that emerge after tilling cannot bolt and bloom until they undergo a vernalization period. Herbicides or tillage can be used to reduce competition from late emerging seedlings.

Dyer's woad can be a problem in alfalfa where irrigation is not used and where the crop is stressed. Infested alfalfa fields can be cultivated in the spring with a flex-tine harrow. Crop rotation in combination with tillage and herbicide management should be used to control dyer's woad and other weeds in alfalfa.

Re-vegetation. Dyer's woad is often found on sites with rocky soils and low productivity making re-vegetation economically marginal in some cases. However, competition from desirable plants will reduce dyer's woad spread. Dyer's woad must be controlled, along with other weeds, and a firm weed-free seedbed prepared on sites that can be cultivated. On rough sites where cultivation is not possible, a surface disturbance such as fire or grazing may be needed to provide safe sites for a perennial grass planting. Establishing competitive perennial grasses on disturbed land, followed by prescribed grazing management to maintain grass vigor will suppress dyer's woad and prevent spread by seed. 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, timing of seeding, and seeding methods. Where herbicides have been applied, chemical carryover should be assessed prior to planting permanent vegetation.

IPM of Dyer's Woad in Montana: Containment and Local Eradication of Dyer's

In 1984, the Montana Dyer's Woad Cooperative Project was started. The Project is governed by the Montana Dyer's Woad Task Force which sets and communicates a common statewide goal for dyer's woad among landowners, managers, scientists, and the general public, and provides the basis for ongoing dialogue. The Task Force also hires a Project Coordinator who manages a dyer's woad field crew. Funding for the Montana Dyer's Woad Cooperative Project is provided from the Montana Noxious Weed Trust Fund with matching funds from counties, the University of Montana, and Headwaters Resource Conservation and Development. With years of adequate funding, the Montana Dyer's Woad Cooperative Project has been a pro-active management entity.

Because dyer's woad is considered in the introductory phase of invasion in Montana, the Montana Dyer's Woad Cooperative Project's overall objective is to eradicate the weed from Montana. The Project's four-part IPM approach for obtaining the objective includes: 1) early detection of new infestations including inventorying areas surrounding known infestations for potential spread of dyer's woad, 2) managing known dyer's woad infestations using hand pulling, digging and rouging, herbicide applications, or combinations of these managements, applied bi-weekly throughout the growing season, 3) monitoring known infestations with a Global Positioning System (GPS) and recording data in the GPS data dictionary, and 4) educating the general public and land managers on dyer's woad identification and management.

To evaluate the success of the Montana Dyer's Woad Cooperative Project, project coordinators used monitoring data to observe the change in the number of counties where dyer's woad was present, evaluated change in infestation size, and predicted population spread based on the 1999 population size and demographic characteristics of dyer's woad. Dyer's woad has been eradicated from nine of 13 counties infested in Montana and infestation sizes have decreased from 480 acres (194 ha) to 6.4 acres (2.6 ha) in the remaining infested counties. In some counties, a containment effort was needed in conjunction with repeated inventories and treatment applications to prevent spread while depleting the seed bank to the point where eradication was possible. If not for the Project, their analysis suggests that some dyer's woad populations would have grown to millions of plants, potentially covering 96,423 acres (39,021 ha) in Montana and costing 1.9 million dollars a year to manage. In comparison, the Project has reduced the total area infested in Montana to 6.4 acres (2.6 ha) and cost the state only $142,000 for the last seven years of management (average $20,286/year). In Montana, dyer's woad eradication from individual counties has been successful due to persistence and on-going cooperative efforts. The project can be used as an example of how to eradicate an invasive species regionally and over the long-term when the weed population is in the introductory phase of invasion.

References

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