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The Phenology and Control of Dyers Woad (Isatis tinctoria) in Northern Utah

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THE PHENOLOGY AND CONTROL OF DYERS WOAD

(_ISATIS_ _TINCTORIA_) IN NORTHERN UTAH

by

William A. Varga

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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ABSTRACT

The Phenology and Control of Dyers Woad

(Isatis Tinctoria) in Northern Utah

by

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Utah State University, 1974

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Department: Plant Science

The purpose of this thesis is to describe dyers woad and to establish means for control of the weed in northern Utah. Logan was chosen for studying germination of the weed, and interaction of dyers woad and alfalfa stands. Collinston was selected for screening trials of herbicides for the control of dyers woad. The thesis contains information on the phenology of dyers woad and suggestions for control of the weed.

(34 pages)

INTRODUCTION

Dyers woad was first observed in Utah in the early twentieth century, but the weed has become an economic problem only in the last twenty years. During that period dyers woad has rapidly spread and infested large tracts of rangeland, alfalfa fields, and in some instances dryland wheat.

Logan and Collinston, Utah are located near the apparent point of introduction of dyers woad in northern Utah at Perry. Logan was chosen as the site for studies involving germination of the weed, and interaction of dyers woad and alfalfa stands. Collinston was selected for screening trials of herbicides for the control of dyers woad. Both studies were considered important to better understand the nature and control of the weed.

REVIEW OF LITERATURE

Dyers woad (Isatis tinctoria) is a relatively new weed in Utah. To more fully understand the characteristics of woad or wad (12) as it was called in thirteenth century England, its early history and etymology, and its commercial use might be examined.

Although relatively new in Utah, woad was well-known centuries before the Christian Era as a medicinal herb (2). Dioscorides described the plant "Isatis" (10) which means a milky-juiced herb (3).

An archaeological find in England dates woad to the Anglo-Saxon Period (12). This evidence is not surprising in view of the fact that when the Romans invaded Britain just before the Christian Era they encountered warriors who had painted themselves with the dye extracted from woad. The British evidently coated themselves with the blue pigment in order to scare their enemies (2).

The etymology of "woad" dates back to the Greeks and Romans, and some correlate its etymology with that of "weed." They postulate a common origin of the two words dating back to early English. The Saxons called August "woed-monath"; the month of weeds (12). "Weed" and "woad" were spelled differently, but sounded much alike. Perhaps the term "weed" developed from accidental usage. In either Germanic or Romance languages "weed" has no intrinsic meaning or self description in itself (12). Possibly, any plant which suddenly appeared profusely after cultivation was likened to "woad" for its well-known habit of sudden appearance in newly plowed ground (10).

Woad is one of the most ancient plant dyes. For this purpose it was first cultivated in England and France. The manufacture of the dye had reached such importance by the thirteenth century that it required international control (2).

The blue dye of woad was used for many centuries to obtain blue cloth. It could be used alone or with other dyes to produce various color combinations. Saxon green is a combination of woad's blue dye and the wild mignonette's yellow dye (2).

Indigotine, which produces the blue coloration, is located in the leaves of woad. The leaves were hand-picked, crushed, and kneeded into balls before drying. The dried leaves were stored until a need for dye making arose. They were then taken to couching houses where they were ground, piled, sprinkled with water, and allowed to ferment for approximately a month. During this time an obnoxious odor issued from the pile, and in sixteenth century England, Queen Elizabeth forbade any woad growing or processing to take place within five miles of any one of her residences.

After fermentation the insoluble indigotine was present, and the material could once again be stored. Later, a further fermentation was induced producing indigo white powder. The cloth was seeded in a solution made from the powder and hung to dry. During the drying process the cloth took on the blue coloration (2). Indigo from the Far East eventually replaced woad, but woad was still cultivated until 1930 in England (10).

It is generally accepted that woad is a native of southeastern Russia and that it spread throughout the estern hemisphere in pre-historic times (12). It occurs in the wild and in cultivation in China, Western Tibet, and Afghanistan. It was cultivated in Europe and still persists wild there although all cultivation has ceased.

Woad was cultivated in Virginia during colonial times, and it still grows wild in the western part of the state (21). It can be found in northeastern California, southeastern Oregon, and Idaho (12). It is listed as a weed in Utah (9). Rydberg observed it in Utah as early as 1917 (17). The earliest specimen in the Utah State University Herbarium was collected by Bassett Maguire at Perry, Utah, in 1932 (15). Other herbarium specimens extend woad's range to Montana on the north, Wyoming on the east, and Sanpete County, Utah on the south (11).

Woad is a bluegreen plant, two to four feet tall. It is a biennial, winter annual, or short-lived perennial plant which may form a rosette in spring or fall and then develops flowers and seeds the next year. Early the following spring and summer it appears as a conspicuous yellow flowering plant and in late summer as a stalk ornamented with winged black fruits.

Woad leaves are blue-green and slightly pubescent. They are of two types: upper leaves which clasp the stalk and lower leaves which do not. Upper leaves are sessile, whereas the lower leaves form a rosette in early spring with each leaf possessing a petiole (or stalk) of its own. A cream colored midrib extends from the base to the tip of all leaves. The large, woody stalks are purple and topped by a compound panicle which displays an umbrella-like inflorescence. Approximately twenty small stalks begin to develop from each rosette in the spring, but only seven or less mature.

Figure 1. Yellow flowering dyers woad plants.

Woad fruits are identified as black samaras or silicles. They hang like ornaments from the umbrella-shaped branches. The fruits are three-fourths inch long and one-fourth inch wide at the widest part. The single or double central seed does not dehisce to release the tiny yellow-brown seed (16).

Woad plants have large, fleshy taproots which in loose, gravelly soils may exceed five feet in depth. Asexual reproduction may occur from this underground root system (7).

Woad prefers the loose alkaline bench soils of northern Utah. In England it is often located in old lime-pits and chalk quarries (10) (12). King states that woad has an alkaline soil requirement (12). We found a thick stand of woad

Figure 2. Mature woad plants.

growing on a mound of introduced soil on the road to Liberty in the south end of Cache Valley. The soil was alkaline and loose. No other plants were growing with dyers woad.

Many mustard relatives of dyers woad serve as hosts for overwintering beet leaf hoppers (Circulifer tenellus) in northern Utah and southern Idaho (19). Curly top, a serious viral disease of sugar beets and tomatoes, is transmitted through the leaf hopper (18). The dense vegetative rosette of dyers woad may provide an excellent host for the overwintering leaf hopper.

Woad is a persistent weed, and its rosette is thought to inhibit the growth of other plants. It is known that other related mustrad plants will take up twice as much nitrogen and phosphorous, four times as much potassium, and four times as much water as a well-developed oat plant (4). Dyers woad may be as destructive in the competitive relationship. In Scott Valley in northern California dyers woad has been replacing annual grasses which were thought to be the culmination of plant succession in the weed community. Young and Evans (21) have found a germination depressant in the fruits of woad. It inhibits germination of other mustards and to some extent it inhibits germination of other plants. In many cases root elongation following germination was stunted. The seeds of dyers woad contain no inhibitor, but the fruits contain the inhibitor which can be removed by leaching (21).

In northern Utah, woad can be controlled mechanically or by herbicides. As a biennial, dyers woad can be removed by digging, hoeing, plowing, etc. while it persists in a vegetative state during its initial year of growth. Dyers woad may also be controlled by herbicides. Higgins and Tovey have stated that tolerance to some herbicides makes dyers woad difficult to control (8). They say that 2,4-D at a rate of 1.5 lb/A is effective if repeat applications are applied. Other chemicals may prove effective upon experimentation. Metribuzin, for example, is effective on most mustards common to the alfalfa growing regions of the intermountain states (20). Metribuzin eliminated tansy mustard (Descurainia pinnata) in experimental wheat fallow in Wyoming (14). 2-sec. butylamine-4-ethylamino-6-methoxy-s-triazine (GS-14254) satisfactorily controlled mustard (Brassica Sp.) in dormant established dryland alfalfa (5).

GS-14254 also gave season long weed control in irrigated Wyoming alfalfa (13). We have noted that other herbicides are effective to some extent on common weeds in alfalfa. Effectiveness may be determined upon experimentation.

MATERIALS AND METHODS

Dawson alfalfa (Medicago sativa) was used exclusively in the greenhouse experiments. Dyers woad fruits (Isatis tinctoria) were collected in 1970 from a natural infestation south of Collinston, Utah, and in 1972 from sites at Beaver Dam and Garland, Utah. Seed from the three locations were used in various greenhouse experiments. In field trials treatments were made to a natural infestation of dyers woad using a bicycle sprayer equipped with 8003 nozzle tips at 30 psi (pounds per square inch) applying 20 gallons of water to the acre. Botanical separations were made at harvest in the greenhouse experiments. Total wet and dry weights were computed for dyers woad and alfalfa in each treatment. The data were statistically evaluated, and the tables are included in the appendix.

Greenhouse Experiments

Germination of dyers woad

Twenty-five fruits of dyers woad were sown in a six inch plastic pot with each pot containing a soil mixture of one-third sand, one-third mountain loam, and one-third perlite to determine the percentage of emergence; ten replications were sown. The fruits were covered with one-eighth inch sifted soil of the same mixture. Each pot was irrigated from above with a hose twice daily. Sixteen days after planting, a visual count of emerged seedlings was recorded.

Dyers woad, a possible overwintering host for the beet leaf hopper (*Circulifer tenellus*)

Four of six dyers woad seedlings growing in an eight by twelve inch metal flat were inoculated with six leaf hoppers per seedling. Leaf hoppers were obtained from a virulent population maintained by the department of Botany and Plant Pathology. Virulence was verified by the infected sugar beets upon which the leaf hoppers were maintained. Leaf hoppers were transferred to and enclosed on dyers woad seedlings in plastic inoculation tubes one inch in diameter and two inches in length. They were removed one month after inoculation. Visual observations were made weekly.

Interaction between dyers woad and alfalfa

Alfalfa seed and dyers woad fruits were sown in rows impressed in a mixture of mountain loam, sand, and perlite in fourteen by eighteen inch flats with ten rows to the flat. Each flat contained a standard population of ninety plants. The dyers woad to alfalfa rows increased through eleven flats from a 10:0 ratio to a 0:10 ratio. The experiment was repeated three times. A similar experiment accompanied the previous one in six inch plastic pots. Seven pots were sown to dyers woad and alfalfa increasing from a 5:0 ratio to a 0:5 ratio. Five replications were sown. Slow release pellets of fertilizer containing nitrogen, phosphorous, and potassium were applied to all flats and plastic pots. Flats and pots were watered twice daily from above using a hose.

All plants were harvested after sixty days. Botanical separations were made; total dry weights were recorded for both plant species.

Influence of dyers woad density on alfalfa yields. The influence of dyers woad on alfalfa production was determined by measuring the total yield of each species in the flats and plastic pots after sixty days. Alfalfa yields were compared using the Duncan's Multiple Range Test to evaluate the effects of increasing dyers woad densities in an alfalfa stand.

Competition of varying densities of dyers woad on nine alfalfa plants. One row of nine alfalfa plants was selected from each flat to demonstrate the competitive relation of varying densities of dyers woad on alfalfa. The additional alfalfa rows in each flat were regarded as filler plants in all cases where the dyers woad to alfalfa densities fell below the standard ninety plants per flat. The nine plants were harvested and dry weights recorded. The data was programmed to a regression model, and results are in the appendix.

Field Experiments

Control of dyers woad

An alfalfa field containing a dense stand of dyers woad was chosen as a site for herbicidal control of the weed. An area of approximately 900 square meters was measured and bounded by stakes in the field. The quadrant was further reduced to four replications with each replication containing nineteen treatments, two meters wide and eight meters long with a stake in each corner. Herbicides were applied April 3, using a bicycle sprayer. Dosages were computed on an active ingredient basis and expressed as amount of herbicide per unit surface area. Surviving dyers woad plants within a square meter area in each treatment were counted one month after application. Analysis of variance was performed on the data and recorded in the appendix.

RESULTS AND DISCUSSION

Greenhouse Experiments

Germination of dyers woad

Two-hundred and five seedlings emerged from the two-hundred and fifty dyers woad fruits planted (Table 1). Within the ten replications, per cent emergence ranged from sixty-four to one-hundred per cent with a mean of eighty-two per cent. This evidence seems to contradict data presented by Young and Evans in laboratory experiments. Their germination experiments were carried out in petri dishes. Dyers woad seed in fruit germination ranged from zero per cent at $3^{\circ}C$. to twelve per cent at $20^{\circ}C$. Perhaps, the depressant in the fruits discussed by Young and Evans was leached from the fruit through irrigation in the greenhouse experiments, whereas the petri dishes disallowed leaching of any depressant.

Dyers woad, a possible overwintering host for the beet leaf hopper (*Circulifer tenellus*)

One month after inoculation dyers woad seedlings were examined for evidence of curly top virus. No symptoms were observed, and dyers woad appeared to be resistant to the virus. Leaf hoppers thrived on the dyers woad, and all leaf hoppers were removed in excellent condition. Leaf hoppers can very possibly overwinter on dyers woad rosettes when mild winters permit. Therefore, dyers woad may serve as a host plant for this disease organism.

Table 1. Emergence of dyers woad seedlings sixteen days after planting

Replication	Number of dyers woad fruits planted	Number of dyers woad fruits emerged	Emergence (%)
1	25	18	72
2	25	20	80
3	25	16	64
4	25	21	84
5	25	18	72
6	25	22	88
7	25	23	92
8	25	20	80
9	25	25	100
10	25	22	88
Mean			82
Total	250	205	

Proximity of the host dyers woad to sugar beet fields in northern Utah may provide for early contamination of sugar beets at the sites. The hypothesis appears to agree with the work of Wallace and Murphy (19) who discussed epidemiology of curly top and weed hosts of the beet leaf hopper.

Interaction between dyers woad and alfalfa

Alfalfa emerged two days prior to dyers woad emergence in all cases. The depressant discussed by Young and Evans (21) and located in the fruits of dyers woad did not appear to inhibit the germination and emergence of alfalfa.

Influence of dyers woad density on alfalfa yields. Dry weight comparison of total alfalfa yields following harvest demonstrated significant reduction in alfalfa yield when it was grown in flats containing the three greatest densities of dyers woad (Table 2) (Figure 3). There was no significant reduction in total alfalfa yields in any of the treatments grown in six inch plastic pots (Figure 4). High degrees of alfalfa density in treatments four through nine may have resulted in their lack of significance from treatment ten. On the other hand, the relatively low populations in treatments one through three produced significant yield reductions when they were compared to treatment ten (Table 2).

Table 2. Influence of dyers woad density on alfalfa yields

Treatment	Plant population/flat		Alfalfa yield* (g)
	dyers woad	alfalfa	
1	81	9	14.50 c
2	72	18	20.77 bc
3	63	27	19.93 bc
4	54	36	35.50 abc
5	45	45	35.67 abc
6	36	54	51.70 abc
7	27	63	52.77 abc
8	18	72	51.07 abc
9	9	81	54.67 ab
10	0	90	70.83 a

*Means within columns followed by the same letter are not significantly different at the 5% level.

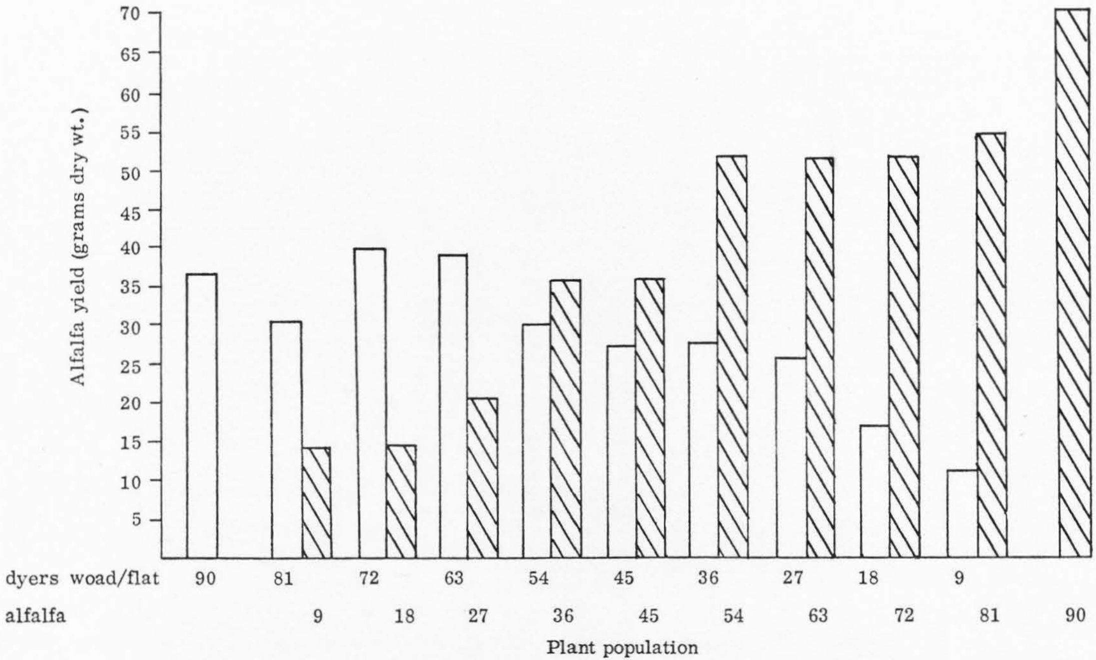

Figure 3. Total flat yields of alfalfa and dyers woad.

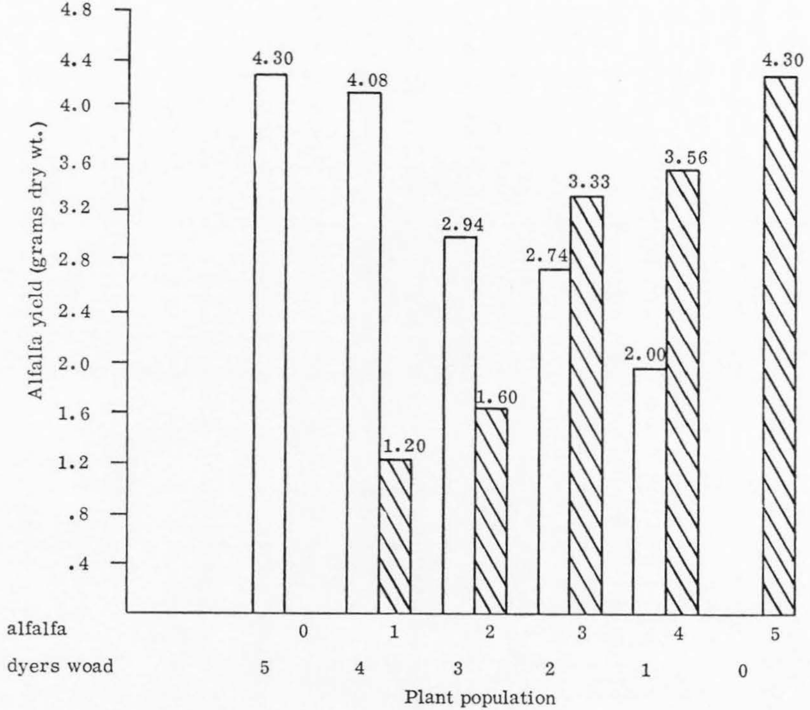

Figure 4. Total plastic pot yields of alfalfa and dyers woad.

Competition of varying densities of dyers woad on nine alfalfa plants. Dyers woad appears to have little effect on alfalfa germination, emergence, and growth during the first sixty days. The regression model (Figure 5) is significant when programmed with individual alfalfa yields versus low to high dyers woad densities. The model was constructed from the formula, $Y = .79 - .0079X + .0002X^2$, where Y equals individual mean yields, and X is a value for each varying density of dyers woad. The quadradic curve obtained from plotting the data (Figure 5) shows little or no competition between alfalfa and high densities of dyers woad. Furthermore, the nine alfalfa plants appear to compete to a great extent with alfalfa filler plants when dyers woad densities are low (Table 3). Perhaps dyers woad and alfalfa occupy dissimilar niches in situations were they grow together. On the other hand, the seedlings and yearling rosettes in this study may not compete as vigorously as does the mature dyers woad plant for nutrients and water. In time, a mature dyers woad plant could possibly crowd out numerous alfalfa plants. Young and Evans (21) mentioned that dyers woad has been replacing annual grasses in northern California. Perhaps dyers woad is simply better suited to the climatic and soil conditions which prevail in the northern Utah and northern California areas. Dyers woad develops quickly following autumn rains. The late fall maturity of the dyers woad rosette may provide the plant an advantage in competing in the field under natural conditions. A thorough investigation of dyers woad competition could demonstrate dyers woad's true nature in the field.

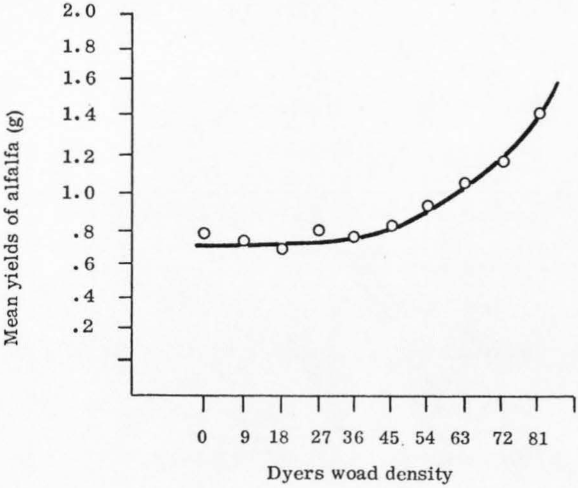

Figure 5. Competition of dyers woad on alfalfa.

Table 3. Yield of nine alfalfa plants when grown with ten densities of dyers woad

Treatment	Plant population/flat			Alfalfa yield (g)
	alfalfa	dyers woad	alfalfa filler	
1	9	81	0	14.85
2	9	72	9	10.35
3	9	63	18	7.83
4	9	54	27	7.02
5	9	45	36	7.20
6	9	36	45	8.55
7	9	27	54	7.20
8	9	18	63	6.12
9	9	9	72	5.85
10	9	0	81	6.93

Field Experiments

Control of dyers woad

Metribuzin at 1.12 kg/ha and glyphosate at 3.36 kg/ha eliminated dyers woad from their respective treatments in all four replications (Table 3). Although both chemicals compared favorably in eliminating dyers woad, metribuzin is a more selective herbicide than glyphosate (Table 3). Metribuzin may have an advantage over glyphosate from this standpoint.

Significant reductions in stand were achieved using GS-14254 at a rate of 2.24 kg/ha, 2,4-D at 1.40 kg/ha, 4(2,4-DB) at rates of 1.40 and 1.12 kg/ha, and metribuzin at .56 kg/ha when compared to the control. GS-14254 at

1.12 kg/ha was not significantly different from the control, but a repeat application of GS-14254 at the same rate would increase herbicidal effectiveness. 2,4-D at 1.12 kg/ha also failed to be significantly different from the control. As Higgins and Tovey (8) have stated, 2,4-D with repeat applications may control dyers woad. Followup treatments may also be necessary using 4(2,4-DB).

The remaining herbicides did not demonstrate adequate dyers woad control. All effective herbicides with the exception of 4(2,4 D-B) at the lower rate were significantly different from dinoseb at 1.40 kg/ha and from pronamide at 2.24 kg/ha (Table 4). Variation in dyers woad population per treatment may have resulted in the limited significance between the various herbicides. For example, pronamide at 1.12 kg/ha is much more effective than pronamide at 2.24 kg/ha as shown in Table 4. Had dyers woad population per treatment been more consistent, increased significance between herbicides in treatments may have been more apparent.

Table 4. Control of dyers woad in alfalfa at Collinston, Utah in 1973

Treatments	Herbicide rate (kg/ha)	Dyers woad* stand (plants/m^2)	Control (%)	Alfalfa injury**
Control		18.00 a*	0	0
Metribuzin	1.12	0.00 c	100	2
Glyphosate	3.36	0.00 c	100	6
GS-14254	2.24	0.50 c	97	0
2,4-D	1.40	0.50 c	97	6
Metribuzin	.56	1.50 c	92	1
4 (2,4 D-B)	1.40	1.75 c	90	1
4 (2,4 D-B)	1.12	4.50 bc	75	1
Cyanazine	1.68	6.50 abc	64	2
Paraquat	1.12	6.50 abc	64	0
2,4-D	1.12	7.50 abc	58	5
Cyanazine	2.80	7.50 abc	58	2
Paraquat	2.24	7.75 abc	57	0
GS-14254	1.12	8.25 abc	54	0
Dinoseb	1.96	9.25 abc	48	0
Pronamide	1.12	9.25 abc	48	0
Paraquat	.56	10.25 abc	43	0
Dinoseb	1.40	13.75 ab	24	0
Pronamide	2.24	17.75 a	1	2

*Means within columns followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

**Injury Index refers to injury rating based on 0 to 10 rating system: 0=no visible injury; 1, 2, 3 = slight injury with little or no reduction in growth; 4, 5, 6 = moderate injury with considerable growth reduction; 7, 8, 9 = severe injury; 10 = all plants killed.

SUMMARY

Studies involving germination, alfalfa-dyers woad competition and interaction, and weed host-beet leaf hopper relationship were conducted in the greenhouse on the Utah State University campus at Logan, Utah. Herbicidal control of dyers woad was evaluated in the field at Collinston, Utah.

An average of eighty-two per cent of dyers woad seed in fruit germinated and emerged within sixteen days. Dyers woad may maintain over-wintering beet leaf hoppers which would provide for early infection of nearby sugar beet fields with the curly top virus. Alfalfa, although significantly reduced from the control when grown with the three highest densities of dyers, appears to compete more with itself than with the weed. The regression model showed a definite trend toward greater individual alfalfa reduction when competing with other alfalfa plants, whereas individual alfalfa yields were higher when competing with high densities of dyers woad.

Metribuzin and glyphosate exhibited excellent control of dyers woad. GS-14254 and 2,4-D at higher rates, and 4(2,4-DB) reduced the weed stand significantly. On the other hand, glyphosate and 2,4-D treatments produced considerable alfalfa injury. Therefore, metribuzin, GS-14254, and 4(2,4-DB) may be used successfully in controlling dyers woad in alfalfa.

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APPENDIX

Table 5. Analysis of variance in yield of alfalfa when grown with nine different concentrations of dyers woad

Source of variation	df	mf	(prob.)
Replication	2	307.6390	
Treatment	9	1014.8495	(0.05)
Replication x Treatment	18	146.0149	

Table 6. Analysis of variance of eighteen treatments for control of dyers woad

Source of variation	df	ms	(prob.)
Replication	3	77.0702	(0.05)
Treatment	18	101.9532	(0.05)
Replication x Treatment	54	27.3294	

Table 7. Analysis of variance of alfalfa yields when grown with four concentrations of dyers woad and without dyers woad

Source of variation	df	ms	(prob.)
Replication	4	0.0529	
Treatment	4	0.2105	
Error	16	0.0839	

Table 8. Analysis of variance of competition between nine alfalfa plants when grown with nine densities of dyers woad

Source of variation	df	ms	(prob.)
Total	29	0.1115	
Model	2	0.8726	(0.05)
Error	27	0.5512	

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