THE EFFECTS OF HERBICIDES ON
ARROWLEAF CLOVER

By

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Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

1976

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1978

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Thesis Approved:

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to his major adviser, Dr. Jim Stritzke, for his advice, time and valuable training throughout the course of study.

Appreciation is also extended to Dr. Eddie Basler and Dr. Paul Santelmann for their advice as members of the authors graduate committee.

Special appreciation is given to the authors wife, Chris and his parents, Mr. and Mrs. Don Conrad, for their assistance, encouragement and interest during the furthering of his education.

The author is indebted to Oklahoma State University Agronomy Department for providing the facilities and the opportunity for this research. Appreciation is also extended to Val Harp for her assistance in typing this manuscript.

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CHAPTER I

INTRODUCTION

There are thousands of acres of pasture in Oklahoma where cattle production could be increased with the introduction of higher yielding and quality forages. Introduced grasses have primarily been used in the past to make these areas more productive. However, the rising cost of nitrogen fertilization has made this practice less desirable. Utley et al. (1977) states that due to the escalated price of fertilizer and accompanying drop in cattle prices, many producers are looking for an alternative to heavy fertilizer use. Arrowleaf clover (*Trifolium vesiculosum* Savi.) may be a good alternative in some areas of Oklahoma. Arrowleaf clover is a late maturing small seeded winter annual legume. It is one of the more aggressive clovers and produces excellent quality forage two months longer than other clovers. It is well adapted to the eastern half of Oklahoma and fits in very well with year round pasture management. High phosphorous levels are critical for maximum growth and this has enhanced the growth of several weed species. Those weeds compete with the arrowleaf for nutrients and water and as a result have lowered forage production and quality. Harvested arrowleaf clover seed is also contaminated by noxious weed seeds such as curly dock (*Rumex crispus*).

At the present time there are no herbicides cleared for use in arrowleaf clover. Consequently, there is a real need to establish selective herbicides for weed control in arrowleaf clover so maximum yields can be obtained. The objectives of this study were; (1) to evaluate the selectivity of several postemergence and preemergence applied herbicides to arrowleaf clover, (2) to determine the weed control with these herbicides, and (3) to select one or more of these herbicides as a candidate for application clearance.

CHAPTER II

LITERATURE REVIEW

Forage and Seed Production of Arrowleaf Clover

In the past, legumes have contributed to forage production. However, with the increasing cost of nitrogen fertilization, they will become more important in the future. Knight (1970) reported that the advantages to using arrowleaf clover and crimson clover (common and scientific names of all plant species reviewed are listed in Table I) in coastal bermudagrass sod were reduction in mineral nitrate requirement, extended grazing, increased total forage production, increased forage quality, and better utilization of land resources. Beaty and Powell (1969) reported that amclo arrowleaf clover was not as productive in coastal bermudagrass sod as crimson clover. They suggest that these differences were due to stand establish problems with arrowleaf clover. When Knight (1970) used arrowleaf and crimson clover in coastal bermudagrass he found total forage production was 47% higher than coastal bermudagrass alone fertilized with 224 kg/ha of nitrogen.

Stiegler and Rommann (1975) reported that in Oklahoma when moisture conditions are adequate, arrowleaf clover will remain vegetative approximately two months longer than other legumes such as crimson clover. Utley et al. (1977) also stated that amclo arrowleaf clover will remain vegetative 4 to 5 weeks longer than dixie crimson

TABLE I

COMMON AND SCIENTIFIC NAMES OF PLANTS

Common Name	Scientific Name
Alfalfa	*Medicago sativa* L.
Alsike clover	*Triflolium hybridum* L.
Annual bromes	*Bromus* spp.
Arrowleaf clover	*Trifolium vesiculosum* Savi.
Bermudagrass	*Cynodon dactylon* (L.) Pers.
Birdsfoot trefoil	*Lotus corniculatus* L.
Cocklebur	*Xanthium* spp.
Crimson clover	*Trifolium incarnatum* L.
Crownvetch	*Coronilla varia* L.
Curly dock	*Rumex crispus* L.
Henbit	*Lamium amplexicaule* L.
Red clover	*Trifolium pratense* L.
Rye	*Secale cereale* L.
Ryegrass	*Lolium* spp.
Sericea lespedeza	*Lespedeza cuneata* (Dumont) G. Don (L. sericea)
Soybean	*Glycine max* (L.) Merr.
Timothy	*Phleum pratense* L.
Hairy vetch	*Vicia villosa* Roth
White clover	*Trifolium repens* L.

clover and will produce more total forage. Bates (1977) reported that arrowleaf clover forage yield, in Oklahoma, was significantly higher than several other pastures legumes.

Seed production also enhanced the introduction of arrowleaf clover because it was very profitable. Some farmers grossed several hundred dollars per acre from harvested seed. Ball et al. (1974) reported that the yield of yuchi arrowleaf clover seed was 630 kg/ha in Alabama. Stiegler and Rommann (1975) reported that if a seed crop is anticipated grazing should cease during the first half of April. Yuchi arrowleaf clover seed yields have been increased over 50% by treatment with GA (4×10^{-1} g/ha) plus SADH (1.12×10^{3} g/ha) (Ball et al. 1974). Common and chemical name for chemicals are listed in Table II. Weed control for seed production of small seeded legumes also appears important since Lee (1964) found that during the three years IPC was applied at 4 pounds per acre as a postemergence treatment, crimson clover seed yields were increased about 200 pounds per acre.

Postemergence Applied Herbicides

Wain (1955) reported that one of the most important properties of 2,4-DB from the agricultural viewpoint is that it could be used postemergence on red and white clover. He stated that a number of noxious weeds could be controlled with 2,4-DB with practically no effect to the legume crops. Hawf and Behrens (1974) reported the tolerance of legumes to 2,4-DB arose from a combination of poorer spray retention, less effective absorption and translocation, and a more rapid degradation of the 2,4-D arising from the beta-oxidation of 2,4-DB. However, Wathana and Corbin (1972) reported that both

TABLE II

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common Name	Chemical Name
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
MCPA	[(4-chloro-o-tolyl)oxy]acetic acid
Bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
2,4-D	(2,4-dichlorophenoxy)acetic acid
Asulam	Methyl sulfanilycarbamate
Dicamba	3,6-dichloro-o-anisic acid
Trifluralin	a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-o-toluidine
Profluralin	N-(cyclopropylmethyl)-a,a,a-trifluoro-2,6-dinitro-N-propyl-p-toluidine
Benefin	N-butyl-N-ethyl-a,a,a-trifluoro-2,6-dinitro-p-toluidine
Dinitramine	N^4,N^4,diethyl-a,a,a-trifluoro-3,5-dinitrotoluene-2,4-diamine
Butralin	N-sec-butyl-4-tert-butyl-2,6-dinitro aniline
Fluchloralin	[N-(2-chloroethyl)-a,a,a-trifluoro-2,6-dinitro-N-propyl-p-toluidine]
Pendimethalin	([N-(1-ethylpropyl)-3,5-dimethyl-2,6-dinitrobenzenamine])
EPTC	S-ethyl dipropylthiocarbamate
MCPB	4-[(4-chloro-o-tolyl)oxy]butyric acid
Dalapon	2,2-dichloropropionic acid
Dinoseb	2-sec-butyl-4,6-dinitrophenol
Vernolate	S-propyl dipropylthiocarbamate
Simazine	2-chloro-4,6-bis(ethylamino)-s-triazine
DCPA	dimethyl tetrachloroterephthalate
Chloropropham	isopropyl m-chlorocarbanilate
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
GA	Gibberellic acid
SADH	Succinic acid 2,2-dimethylhydrazide

cocklebur and soybean beta-oxidized the 2,4-DB to 2,4-D at every stage of growth, but conversion to 2,4-D was less rapid in soybean. Wathana and Corbin (1972) also indicated that at equivalent stages of growth, cocklebur contained higher concentrations of 2,4-D than did the soybean. Linscott et al. (1968) found the mechanism of the resistance of alfalfa to 2,4-DB may result from the synthesis of herbicidally inactive chlorophenoxy compounds. Thus, production of 2,4-D in lethal quantity may be prevented. When almost no broadleaf weeds were present, 0.56 kg/ha of the butoxyethanol ester and 0.85 kg/ha of the dimethylamine salt of 2,4-DB caused no yield reductions of seedling alfalfa (Peters and Lowance 1972). Leavitt and Dunster (1969) reported alfalfa forage yields were increased 1300 pounds per acre when treated with 0.56 kg/ha of 2,4-DB.

Mixtures of 2,4-DB with other herbicides have also been evaluated on alfalfa. Alfalfa was not injured to any extent and good weed control was obtained with 2,4-DB in combination with dalapon or EPTC (Peters 1964). Wakefield and Skaland (1965) reported that application of 2,4-DB (2.24 kg/ha) plus dalapon (2.24 kg/ha) effectively controlled weeds after emergence in alfalfa and had no effect on the number of alfalfa plants established.

Response of red clover and birdsfoot trefoil to 2,4-DB has been more variable. Darwent and Pankiw (1976) reported severe epinastics, delayed flowering, and reduction in seed yields when red clover was treated with 2,4-DB at rates necessary for adequate weed control. However, Peters and Lowance (1972) reported that 2,4-DB (0.85 kg/ha) had no effect on red clover populations and significantly increased forage yield.

Peters (1964) also reported very little damage to birdsfoot trefoil with 2,4-DB. Wakefield and Skaland (1965) reported that some birdsfoot trefoil seedling injury was apparent when 2,4-DB (2.24 kg/ha) and dalapon (2.24 kg/ha) were applied.

Crownvetch appears to be less tolerant to 2,4-DB. Peters and Lowance (1971) reported that crownvetch was injured by 2,4-DB and that the herbicide could be justified only where stands would be lost without broadleaf weed control measures. Peters and Stritzke (1965) found that crownvetch tolerated postemergence treatment with dalapon, but 2,4-DB plus dalapon reduced stands more than 75%. Cope et al. (1973) also noticed that 2,4-DB caused serious injury to crownvetch and ladino white clover. Currently, the dimethyl amine salt of 2,4-DB is labeled for application on the following small seeded legumes: alfalfa, birdsfoot trefoil and alsike, ladino and red clovers.

The influence of other postemergence herbicides on small seeded legumes has also been evaluated. Lee (1964) reported that crimson clover tolerated higher rates of MCPA without reduction in seed yield when the herbicide was applied in December or February. Darwent and Pankiw (1976) reported that MCPB, MCPA, and bromoxynil have considerable potential for the control of annual or winter annual broadleaf weeds in red clover grown for seed. However, Lee (1975) reported that bromoxynil was selective to white clover, but failed to control the winter annual broadleaf and grass weeds. Zaleski (1967) reported that MCPB had no effect on the proportion of white clover/old native grasses and had no effect on white clover seed yield. Peters and Lowance (1971) stated that bromoxynil controlled broadleaf weeds but injured seedling crownvetch and reduced its vigor. Cope et al. (1973)

indicated that bromoxynil did control broadleaf weeds but also caused severe injury to white clover and crownvetch. Peters and Lowance (1972) also stated that when no weeds were present, bromoxynil (0.56 kg/ha or greater) significantly reduced forage yields of red clover. Asulam at 1.0, 2.0 and 4.0 kg/ha (Brock 1972) significantly increased red clover forage yields. Savoy and Soper (1973) reported that total herbage yields of ryegrass/timothy swards were not altered by asulam treatment, but ryegrass formed 98% of the yield compared to 88% in the untreated plots.

Smith (1975) reported the order of increasing influence of several herbicide solutions on arrowleaf clover seedling establishment to be as follows: 2,4-DB < 2,4,5-T = 2,4-D < MCPA = dicamba.

Preemergence Applied Herbicides

Preplant incorporated applications of dinitroanaline herbicides have been extensively evaluated on many of the small seeded legumes. Peters and Lowance (1971) reported that dense and vigorous stands of crownvetch were obtained when benefin or trifluralin were used before planting. Linscott and Hagin (1974) also reported that benefin (2 kg/ha) incorporated preplanting plus dinoseb (0.5 kg/ha) consistently resulted in good weed control and excellent crownvetch establishment. However, Brock (1972) reported a significant reduction in red clover seed yield with 0.5 or 1.0 kg/ha of trifluralin. Cope et al. (1973) found that benefin applied at 1.3 kg/ha significantly reduced alfalfa and ladino clover stands and early vigor, but had not effect on crownvetch. Buchanan and Burns (1968) reported early stunting of sericea lespedeza treated with benefin, but it was not apparent at the end of the growing season. They also noted that benefin gave acceptable control of annual grasses and some broadleaf weeds. Benefin has also shown promise for weed control in arrowleaf clover (Buchanan and Hoveland, 1971).

Thiocarbamate herbicides have also shown promise for weed control in small seeded legumes. Cope et al. (1973) reported that preplant incorporation of EPTC and vernolate provided excellent weed control and insignificant injury to alfalfa, ladino white clover and crownvetch. Wakefield and Skaland (1965) reported preplant incorporated use of EPTC (4.48 kg/ha) resulted in a relatively weed free environment for the establishment of alfalfa and birdsfoot trefoil. However, Schreiber (1960) concluded that EPTC (8.96 kg/ha) as a surface application did not satisfactorily control broadleaf or grass weeds. Also, EPTC did not control broadleaf weeds in alfalfa and birdsfoot trefoil as well as 2,4-DB, but EPTC indicated superior grass control (Peters 1964). Crimson clover was not seriously injured and fair to good weed control was obtained by EPTC and IPC both at 6.72 kg/ha (Lee 1964). Buchanan and Burns (1968) reported that EPTC (5.4 and 10.8 kg/ha) caused considerable stunting of sericea lespedeza which persisted throughout the growing season. Peters and Lowance (1971) reported dense and vigorous stands of crownvetch were consistently established by using preplant treatment of EPTC. Linscott and Hagin (1974) also noted weed control during establishment of crownvetch by applying EPTC before planting and simazine between seeded rows at planting. Buchanan and Hoveland (1971) reported satisfactory weed control in arrowleaf clover with DCPA and chloropropham.

CHAPTER III

METHODS AND MATERIALS

Postemergence Studies

The postemergence studies were located at Calera, Ada and Eufaula, Oklahoma. The studies will be referred to as location I, II and III, respectively. Rainfall at locations I, II and III is given in Table III. Water was applied once in the fall at location I by sprinkler irrigation. See Table IV for the herbicide treatments applied at each area. Statistical design for each area was a randomized complete block. Location I, II and III had three, four and four replications, respectively. The plots size at each location was 2.13 x 7.62 meters. All herbicide treatments were broadcast applied with a carbon dioxide sprayer at 2.1 ksc and 262 l/ha carrier volume. Plot information and spraying conditions for each location are given in Table V. The arrowleaf clover at locations I and II came from volunteer seed of the previous year's crop. Location III was cultivated twice with an offset disk and then seeded in the fall with a cyclone spreader at 6.72 kg/ha of scarified and innoculated arrowleaf clover seed. Following seeding, the area was cultivated once with a spring tooth harrow. The influence of the herbicides on arrowleaf clover were determined by the following means: visual damage, forage production, seed yield and germination, and the weight of 500 seeds.

TABLE III

RAINFALL[1/]

Month	Location I	II	III	IV	V
	(cm)	(cm)	(cm)	(cm)	(cm)
September	----	1.30	8.74	1.30	2.69
October	----	10.13	11.91	10.13	6.93
November	8.97	2.97	2.08	2.97	0.51
December	----	4.39	5.00	4.39	0.71
January	0.41	3.56	4.70	3.56	1.68
February	2.84	4.39	4.83	4.39	4.17
March	5.38	13.00	16.41	13.00	6.65
April	18.19	6.25	7.42	6.25	3.18
May	14.86	16.26	14.68	16.26	17.58
June	10.62	6.17	8.10	6.17	5.82
July	5.77	8.38	10.82	8.38	8.33

[1/]Location I is 1975-1976 data. Locations II, III, IV and V is 1976-77 data.

- Means data not available.

TABLE IV

POSTEMERGENCE APPLIED HERBICIDES AND RATES

Herbicide	Location I	Location II	Location III
2,4-DB[2]	0.56,1.12[1]	0.56,1.12	0.56,1.12
2,4-D	0.56,1.12	0.56,1.12	0.56,1.12
Bromoxynil	0.56	0.56,1.12	0.56,1.12
MCPA[2]	0.56	0.56,1.12	0.56,1.12
2,4-D[3]	0.56		
Asulam	1.12,2.24		
2,4-D[2] + Dicamba	0.42+0.14, 0.84+0.28		

[1] Rates in kg/ha.
[2] The dimethyl amine salt.
[3] The butoxyethanol ester.

TABLE V

PLOT INFORMATION AND SPRAYING CONDITIONS

	Location				
	I	II	III	IV	V
Soil	Dennise loam	Stephenville fine sandy loam	Parsons very fine sandy loam	Stephenville fine sandy loam	Parsons silt loam
Date Treated	March 31, 1976	April 6, 1977	April 6, 1977	October 6, 1976	September 20, 1976
Dry bulb	$19^{\circ}C$	$24^{\circ}C$	$19^{\circ}C$	$18^{\circ}C$	$24^{\circ}C$
Wet bulb	$12^{\circ}C$	$15^{\circ}C$	$12^{\circ}C$	$12^{\circ}C$	$17^{\circ}C$
Soil temperature (10 cm)	$17^{\circ}C$	$14^{\circ}C$	$13.5^{\circ}C$	$17.5^{\circ}C$	$24^{\circ}C$
Wind speed and direction	2-3 mph, S to SE	3-6 mph, S to SW	1 mph, S	5 mph, N	5-10 mph, NNW
Soil Moisture	Good	Very good	Very good	Top 15 cm good	Top 10 cm good
Vegetative height at spraying					
Arrowleaf clover (yuchi)	5-15 cm	5-15 cm	5-10 cm	----	----
Curly Dock	----	8-18 cm	5-15 cm	----	----
Annual Bromes	----	3-15 cm	3-13 cm	----	----

At location I the herbicides were applied March 31, 1976. Visual ratings (0 to 10, see Table VII for explanation of scale) were taken May 12, 1976. Forage yields were obtained from a 0.418 square meter sample in each plot and were taken June 10, 1976 when the arrowleaf clover was in full bloom. Seed yields were taken from a 0.836 square meter plot sample on July 10, 1976. Five hundred seeds from each plot were weighed to see if the herbicide had any influence on maturity or shriveling of the seed. One hundred of these seeds were then scarified and placed in a germinator to determine viability. Location I was essentially weed free.

Locations II and III were selected because of their weed infestation, especially curly dock. Each location contained seedling and established curly dock. At locations II and III the dock infestation, was light and moderate, respectively. Other broadleaf and annual brome weeds were also present. Therefore, the additional factors of broadleaf weed yield, annual brome yield and dock seed heads per plot were also evaluated. These additional factors were determined the same day arrowleaf clover forage yields were taken.

The herbicides were applied to locations II and III on April 6, 1977. Visual ratings were taken April 19 and 28 at locations II and III, respectively. Visual ratings were based on a zero to ten scale with zero indicating no damage and ten indicating dead plants. Forage production was obtained from a 0.418 square meter sample at both locations. Forage samples were taken June 2, 1977 at both locations. Percent by weight of arrowleaf clover, annual bromes and broadleaf weeds were estimated prior to harvesting. Seed yields were obtained from a 1.115 square meter sample in each plot. Seed yields were taken

July 18 and 19 at locations II and III, respectively. The weight of 500 seeds and germination were also obtained as previously described.

Preemergence Studies

The preemergence studies were located at Ada and South Coffeyville, Oklahoma. These studies will be referred to as locations IV and V, respectively. Each location included the same herbicide treatments (Table VI). Rainfall, plot information and spraying conditions are given in Tables III and V, respectively. The statistical design for both locations was randomized complete block with four replications. The plot size at each location was 2.13 x 7.62 meters. All herbicide treatments were broadcast applied with a carbon dioxide sprayer at 2.1 ksc and 262 l/ha of carrier volume. After application each herbicide was incorporated twice with an offset disk approimxately 13 centimeters deep into the soil. The arrowleaf clover was volunteer from the previous year's seed. The factors used to determine the influence of the herbicides to arrowleaf clover were: seedling counts, weed seedling counts and arrowleaf clover forage production.

At location IV the herbicides were applied October 6, 1976. Seedling counts of arrowleaf clover and weeds were taken from two 0.09 square meter quadrats on March 24, 1977. Arrowleaf clover forage yields were obtained from a 0.418 square meter plot sample taken June 2, 1977.

Location V was treated September 20, 1976. Seedling counts and forage yields were obtained in the same manner except they were taken March 23 and May 25, 1977, respectively.

TABLE VI

PREEMERGENCE APPLIED HERBICIDES AND RATES

Herbicide	Rate (kg/ha)
Trifluralin	0.84,1.68
Profluralin	0.98,1.96
Benefin	1.26,2.52
Butralin	2.24,4.48
Dinitramine	0.56,1.12
Fluchloralin	1.12,2.24
Pendimethalin	1.12,2.24
EPTC	3.36,6.72

All data was analyzed using a two way classification analysis of variance. Statistical differences were evaluated using Duncan's Multiple Range Test at the five percent level.

CHAPTER IV

RESULTS AND DISCUSSION

Postemergence Locations

Arrowleaf clover visual ratings for all three postemergence locations are given in Table VII. Injury with 2,4-DB varied from very little to slight damage depending on rate and location. At location I and II visual injury was 1 for both rates of 2,4-DB. At location III there was more injury and a rating of 2 and 3 was recorded for the 0.56 and 1.12 kg/ha rates of 2,4-DB, respectively. This increased damage may be due to the smaller plants at location III at the time of application. MCPA visual damage varied from very little to severe. At 0.56 kg/ha the ratings were 1, 5 and 3 for locations I, II and III, respectively. At 1.12 kg/ha the visual damage was severe with ratings of 7 and 5 for locations II and III, rexpectively. Bromoxynil (0.56 kg/ha) caused no visual damage at location I, however severe visual damage was indicated at locations II and III. Visual damage with 2,4-D amine was very variable. The low rate of 2,4-D amine at location I caused little injury. However, the remaining rates (low and high) caused severe injury above 5 at other locations. The ester of 2,4-D and combinations of 2,4-D plus dicamba treatments caused severe damage at location I. Consequently they were not applied at locations II and III. Asulam (0.56 and 1.12 kg/ha) caused very

TABLE VII

ARROWLEAF CLOVER VISUAL RATINGS[1/]

Treatment	Rate (kg/ha)	Location		
		I	II	III
Check	----	0	0	0
2,4-DB	0.56	1	1	2
2,4-DB	1.12	1	1	3
MCPA	0.56	1	5	3
MCPA	1.12	--	7	5
Bromoxynil	0.56	0	6	6
Bromoxynil	1.12	--	8	7
2,4-D Amine	0.56	1	5	7
2,4-D Amine	1.12	5	7	8
2,4-D Ester	0.56	5	--	--
Asulam	1.12	1	--	--
Asulam	2.24	1	--	--
2,4-D + Dicamba	0.42+0.14	8	--	--
2,4-D + Dicamba	0.84+0.28	9	--	--

[1/]Based on 0-10 scale; 0=no damage, 10=dead plants.
--Means treatment not applied at that location.

little visual damage at location I but was not applied at location II and III.

Arrowleaf clover forage yields are given in Table VIII. There was no difference in forage yield between the 2,4-DB plots and the check plots at all locations except at location III where 2,4-DB (0.56 kg/ha) significantly increased the yield to 7164 kg/ha. There was also no significant forage yield reductions in the MCPA plots treated with the 0.56 kg/ha rate but a reduction to 3331 kg/ha was noted at location III with the 1.12 kg/ha rate. Forage yields from plots treated with 0.56 kg/ha of bromoxynil tended to be less than untreated plots and this reduction was significant at locations II and III. Both treatments of 2,4-D amine and the combination of 2,4-D plus dicamba caused reduction in forage yields at all locations. There was no forage reduction in the plots treated with asulam.

Arrowleaf clover seed yields are given in Table IX. Very few treatments had an effect on arrowleaf clover seed yields. Only combinations of 2,4-D plus dicamba reduced seed yields at location I. However, MCPA (0.56 kg/ha), bromoxynil (0.56 kg/ha) and 2,4-D (1.12 kg/ha) reduced the seed yield at location II and both rates of 2,4-D reduced the seed yield at location III.

Arrowleaf clover seed germination is given in Table X. Some differences were noted but generally varied more by location than by herbicide. Bromoxynil (0.56 kg/ha), 2,4-D (1.12 kg/ha) and asulam (1.12 kg/ha) treatments reduced germination at location I. However at location II and III, there were no reductions in germination and seed from some of the herbicide plots actually germinated better than seed from untreated areas.

TABLE VIII

ARROWLEAF CLOVER FORAGE YIELD

Treatment	Rate (kg/ha)	Location I	Location II	Location III
		(kg/ha)	(kg/ha)	(kg/ha)
Check	----	8940 a	4430 a-c	5230 b
2,4-DB	0.56	8520 a	6000 a	7160 a
2,4-DB	1.12	8250 a	4980 ab	5660 ab
MCPA	0.56	8130 a	4670 ab	5130 b
MCPA	1.12	----	4470 a-c	3330 c
Bromoxynil	0.56	8000 a	2850 cd	1390 d
Bromoxynil	1.12	----	2280 de	510 d
2,4-D Amine	0.56	6500 b	3590 b-d	1060 d
2,4-D Amine	1.12	4440 c	1130 e	260 d
2,4-D Ester	0.56	3810 c	----	----
Asulam	1.12	8070 a	----	----
Asulam	2.24	8970 a	----	----
2,4-D + Dicamba	0.42+0.14	2500 d	----	----
2,4-D + Dicamba	0.84+0.28	520 e	----	----

Numbers followed by the same letter are not significantly different at the five percent level.
Weed infestation in the check plots at location I, II and III was weed free, light and moderate, respectively.

TABLE IX

ARROWLEAF CLOVER SEED YIELD

Treatment	Rate (kg/ha)	Location I (kg/ha)	Location II (kg/ha)	Location III (kg/ha)
Check	----	700 ab	300 a	320 a-d
2,4-DB	0.56	770 ab	250 ab	380 ab
2,4-DB	1.12	700 ab	250 ab	340 a-c
MCPA	0.56	820 ab	150 bc	420 a
MCPA	1.12	----	260 ab	320 a-d
Bromoxynil	0.56	870 ab	150 bc	220 b-e
Bromoxynil	1.12	----	170 a-c	200 c-e
2,4-D Amine	0.56	830 ab	200 a-c	150 e
2,4-D Amine	1.12	660 ab	60 c	180 de
2,4-D Ester	0.56	700 ab	----	----
Asulam	1.12	960 a	----	----
Asulam	2.24	840 ab	----	----
2,4-D + Dicamba	0.42+0.14	540 b	----	----
2,4-D + Dicamba	0.84+0.28	120 c	----	----

Numbers followed by the same letter are not significantly different at the five percent level.

TABLE X

ARROWLEAF CLOVER GERMINATION

Treatment	Rate (kg/ha)	Location I	II	III
		(%)	(%)	(%)
Check	----	76 a	84 bc	82
2,4-DB	0.56	69 a-c	87 a-c	85
2,4-DB	1.12	74 ab	86 a-c	86
MCPA	0.56	73 a-c	87 a-c	83
MCPA	1.12	----	91 a	91
Bromoxynil	0.56	59 d	83 c	82
Bromoxynil	1.12	----	89 ab	75
2,4-D Amine	0.56	68 a-c	91 a	74
2,4-D Amine	1.12	65 cd	84 bc	80
2,4-D Ester	0.56	76 a	----	----
Asulam	1.12	66 b-d	----	----
Asulam	2.24	68 a-c	----	----
2,4-D + Dicamba	0.42+0.14	74 ab	----	----
2,4-D + Dicamba	0.84+0.28	75 a	----	----
				NS

Numbers followed by the same letter are not significantly different at the five percent level.

The weight of 500 seeds is given in Table XI. The weight of the seeds was also reduced at location I by some of the herbicide treatments [2,4-D amine (1.12 kg/ha), 2,4-D ester (0.56 kg/ha) and 2,4-D amine plus dicamba (0.85 + 0.28 kg/ha)]. However, at location II and III there was no differences in seed weight due to treatment.

Broadleaf weed yields (Table XII) are a good indicator of the difference in weed infestations at locations II and III. The broadleaf weed yield for the check plots at locations II and III was 376 and 841 kg/ha, respectively. At location II, all herbicide treatments except bromoxynil (1.12 kg/ha) reduced broadleaf weed yields. At location III, neither rate of bromoxynil reduced the yields of broadleaf weeds. The low rate of 2,4-D did not reduce broadleaf weed yields at location III.

There was also annual brome species in the test area. Some of the herbicides effected their yield (Table XII). These herbicides are often used for grass release so presumably would have little direct effect on the bromes. However, significant increases in annual bromes resulted in plots treated with bromoxynil and 2,4-D. The increased yield of the annual bromes may be due to less competition in the plots where the herbicide damaged arrowleaf clover. There was no increase of annual bromes in plots treated with 2,4-DB and MCPA.

Effect of the various treatments on curly dock are given in Table XIII. The check plots at locations II and III had 5 and 29 seed heads, respectively. At location II, early damage was not very apparent with some of the treatments but seed heads were significantly reduced by all treatments. At location III, early injury ratings were a good indicator of dock seed stalks remaining. Only slight

TABLE XI

WEIGHT OF 500 SEEDS

Treatment	Rate (kg/ha)	Location I	II	III
		(mg)	(mg)	(mg)
Check	----	620 a	580	700
2,4-DB	0.56	620 a	540	710
2,4-DB	1.12	610 a	560	700
MCPA	0.56	600 ab	560	700
MCPA	1.12	----	540	710
Bromoxynil	0.56	620 a	560	690
Bromoxynil	1.12	----	550	720
2,4-D Amine	0.56	590 ab	570	720
2,4-D Amine	1.12	570 b	530	700
2,4-D Ester	0.56	560 b	----	----
Asulam	1.12	620 a	----	----
Asulam	2.24	630 a	----	----
2,4-D + Dicamba	0.42+0.14	620 a	----	----
2,4-D + Dicamba	0.84+0.28	570 b	----	----
			NS	NS

Numbers followed by the same letter are not significantly different at the five percent level.

TABLE XII

WEED YIELDS

Treatment	Rate (kg/ha)	Location II Broadleaves (kg/ha)	Location III Broadleaves (kg/ha)	Location II Annual Bromes (kg/ha)	Location III Annual Bromes (kg/ha)
Check	----	380 b	840 b	290 a	570 a
2,4-DB	0.56	20 a	50 a	280 a	550 a
2,4-DB	1.12	0 a	20 a	170 a	570 a
MCPA	0.56	0 a	70 a	690 ab	800 ab
MCPA	1.12	0 a	40 a	210 a	840 a-c
Bromoxynil	0.56	80 a	1020 b	1000 bc	1660 cd
Bromoxynil	1.12	220 ab	1150 b	1280 c	1600 b-d
2,4-D	0.56	0 a	870 b	660 ab	1720 d
2,4-D	1.12	0 a	140 a	1550 c	2580 e

Numbers followed by the same letter are not significantly different at the five percent level.

TABLE XIII

CURLY DOCK VISUAL RATINGS AND SEED HEADS/PLOT

Treatment	Rate (kg/ha)	Location			
		II	III	II	III
		Visual Ratings		Seed Heads/Plot	
Check	----	1	0	5 b	29 b
2,4-DB	0.56	1	4	0 a	0 a
2,4-DB	1.12	3	4	0 a	1 a
MCPA	0.56	4	5	0 a	0 a
MCPA	1.12	6	7	0 a	0 a
Bromoxynil	0.56	2	1	2 a	25 b
Bromoxynil	1.12	3	1	1 a	35 b
2,4-D	0.56	4	5	0 a	1 a
2,4-D	1.11	4	7	0 a	0 a

Numbers followed by the same letter are not significantly different at the five percent level.

damage was noted in the bromoxynil plots and curly dock seed stalks remaining were the same as in the untreated plots. All other treatments significantly reduced the number of seed stalks. This would reduce contamination of harvested arrowleaf clover seed.

2,4-DB was the only postemergence herbicide evaluated that consistently indicated selectivity to arrowleaf clover and control of the broadleaf weeds. Therefore, it should be considered as a candidate for application clearance.

Preemergence Locations

Results from seedling counts and forage yield at location IV (Table XIV) indicate that the herbicide treatments had no effect on hairy vetch or curly dock. However, there were differences in arrowleaf clover seedling counts due to treatment. The highest counts (100 plants/m^2) were obtained from the plots treated with EPTC (6.72 kg/ha), fluchloralin (1.12 kg/ha) and benefin (1.26 kg/ha). There were only 39 plants per square meter in the check plots but no significant differences in forage yield existed with any of the treatments.

Results from seedling counts and forage yield at location V (Table XV) indicate that the herbicide treatments did significantly effect the seedling counts of rye and henbit but had no effect on arrowleaf clover seedling counts and forage yields. Several of the treatments effectively controlled rye. There was only 6 plants in the plots treated with 6.72 kg/ha of EPTC compared to 50 plants per square meter in the check plots.

Henbit counts were very variable but were highest in the plots treated with 3.36 kg/ha of EPTC. This increase of henbit might be

TABLE XIV

SEEDLING COUNTS AND FORAGE YIELD AT LOCATION IV

Treatment	Rate (kg/ha)	Hairy Vetch ($1.0m^2$)	Curly Dock ($1.0m^2$)	Arrowleaf Clover ($1.0m^2$)	Arrowleaf Clover Forage Yield (kg/ha)
Check	----	22	6	40 d	4970
Trifluralin	0.84	22	11	70 a-d	7580
Trifluralin	1.68	11	0	40 cd	7070
Benefin	1.26	11	0	100 a	5660
Benefin	2.52	17	6	90 ab	5170
Pendimethalin	1.12	6	0	80 a-c	3910
Pendimethalin	2.24	11	6	80 a-c	5550
Butralin	2.24	39	0	70 a-d	4790
Butralin	4.48	28	0	50 b-d	5280
Dinitramine	0.56	17	6	60 b-d	5240
Dinitramine	1.12	6	0	50 b-d	4660
Profluralin	0.98	11	6	40 b-d	4080
Profluralin	1.96	17	0	50 b-d	4700
Fluchloralin	1.12	28	0	100 a	5640
Fluchloralin	2.24	11	0	50 cd	4210
EPTC	3.36	61	0	40 cd	3450
EPTC	6.72	22	6	100 a	4450
		NS	NS		NS

Numbers followed by the same letter are not significantly different at the five percent level.

TABLE XV

SEEDLING COUNTS AND FORAGE YIELD AT LOCATION V

Treatment	Rate (kg/ha)	Rye ($1.0m^2$)	Henbit ($1.0m^2$)	Arrowleaf Clover ($1.0m^2$)	Arrowleaf Clover Forage Yield (kg/ha)
Check	----	50 d	44 a-c	17	3170
Trifluralin	0.84	33 b-d	33 a-c	50	4860
Trifluralin	1.68	17 ab	11 a	11	3350
Benefin	1.26	44 cd	28 a-c	56	1380
Benefin	2.52	17 a-c	28 a-c	44	3800
Pendimethalin	1.12	28 a-d	17 ab	28	2970
Pendimethalin	2.24	22 a-c	28 a-c	28	710
Butralin	2.24	33 b-d	61 c	50	3420
Butralin	4.48	33 a-d	44 a-c	22	1150
Dinitramine	0.56	50 d	17 ab	56	2820
Dinitramine	1.12	11 ab	22 a-c	17	1410
Profluralin	0.98	28 a-d	22 a-c	44	3520
Profluralin	1.96	28 a-d	17 ab	33	4710
Fluchloralin	1.12	33 a-d	28 a-c	50	3960
Fluchloralin	2.24	28 a-d	11 a	22	2620
EPTC	3.36	11 ab	111 d	28	4200
EPTC	6.72	6 a	52 b-c	6	1970
				NS	NS

Numbers followed by the same letter are not significantly different at the five percent level.

the result of rye control and lack of residual activity of EPTC. There were indications of reduced henbit populations with several of the dinitroanaline herbicides but these differences were not significant at the five percent level.

The arrowleaf clover stand at location V (Table XV) was confounded by the rye and dry weather. There were very few arrowleaf clover plants in the plots treated with 6.72 kg/ha of EPTC and forage production from these plots was only 1974 kg/ha.

No conclusive data was obtained from the preemergence studies. Therefore, additional research is needed to find an applicable and effective preemergence applied herbicide. One of the major problems was the slow emergence of arrowleaf clover in the fall. Also the failure of the arrowleaf clover to develop enough canopy to shade the soil until March of the following spring resulted in an extended period in which weeds could emerge.

CHAPTER V

SUMMARY

Field studies were conducted to determine the effects of several postemergence and preemergence applied herbicides on arrowleaf clover. At the present time there are no herbicides cleared for weed control in arrowleaf clover.

Herbicides were postemergence applied at three different locations. Of the postemergence applied herbicides evaluated, 2,4-DB was consistently selective to arrowleaf clover and adequately controlled the weeds including seed stalk formation of curly dock. MCPA also controlled the weeds but was not consistently selective to arrowleaf clover. Bromoxynil, 2,4-D and the combination of 2,4-D plus dicamba caused severe damage to arrowleaf clover. Asulam was not harmful to arrowleaf clover in the one study where it was applied.

Results from the screening of preemergence applied herbicides were variable and conclusive data was not obtained. Although differences in weed and arrowleaf clover seedling counts were obtained, there was no difference in arrowleaf clover forage yield. The results were confounded by slow emergence of arrowleaf clover in the fall thus allowing an extended period of time in which weeds could emerge. Further research is needed to find selective and effective preemergence applied herbicides for use in arrowleaf clover.

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