THE EFFECTIVENESS OF THE BIPYRIDILIUM HERBICIDES IN PASTURE IMPROVEMENT PROJECTS

A THESIS

Submitted to

The Faculty of Graduate Studies and Research
The University of Manitoba

In Partial Fulfilment of the Requirements
for the Degree of Master of Science

By

GARRY G. BOWES

April 1966

ABSTRACT

Spring applications of paraquat at rates of 1/4, 1/2 and 1 pound per acre were evaluated in conjunction with sod-seeding of alfalfa for native bluegrass pasture improvement. Only at the one pound per acre rate was the suppression of resident vegetation sufficient to permit establishment of alfalfa.

Single application of 2,4-D:2,4,5-T at 24 ounces per acre prior to treatment and sod-seeding was relatively ineffective in controlling perennial forbs found in native pastures. In addition, the chemical residues in the soil following treatment with the phenoxy herbicides prevent the germination of sod-seeded legumes in the year of application. Fall application of paraquat at rates up to 1-1/2 pounds per acre was ineffective in suppressing the resident vegetation the following spring.

Paraquat applied in the spring at rates of 1/2, 1 or 2 pounds per acre suppressed or controlled dense stands of wild barley sufficiently to permit the successful establishment of spring seeded alsike clover.

Paraquat at 2 pounds per acre in combination with isocil at 2 pounds per acre applied as a split application separated by a 4 to 6 week interval was more effective in controlling couchgrass than a single application of dalapon at 25 pounds per acre or TCA at 60 pounds per acre. Four rotovations over a period of a year were equal to 6 paraquat treatments, each at 2 pounds per acre applied approximately at monthly intervals. Fall application of paraquat at rates up to 2 pounds per acre suppressed couchgrass for approximately one month in the following spring.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to Dr. George Friesen and to Dr. A. K. Storgaard for their suggestions and guidance in the work and in the preparation of this thesis.

The Funds which made this research possible were provided by Canadian Industries Limited Research Fellowships.

TABLE OF CONTENTS

Table of Contents

LIST OF TABLES

Table	List of Tables	Page

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

During the past 20 years arable weed, particularly annual weed, control has developed to the point where a specific chemical can be recommended for a specific weed problem. However, selective control of many perennial weeds has not been developed to the same extent and many problems associated with the control of these weeds in native pastures, waste areas, and cropped lands still exist.

Approximately 6 million acres of arable land are utilized for pasture in Manitoba. Of this total about 5 million acres are native or unimproved pasture which are low in productivity and are usually infested with herbaceous and woody perennial weeds.

Cultural methods, such as breaking and reseeding, have been universally used to improve unproductive pastures. Recently chemical renovation, in which chemicals are used to suppress or kill the resident vegetation prior to direct sod-seeding, has supplanted cultural renovation in parts of New Zealand and the United Kingdom.

Wild barley (Hordeum jubatum L.) is a weedy grass in many low set areas in native pastures. Under high water table conditions, wild barley becomes very competitive and persistent. Wild barley is completely useless as a forage crop because of its sharp awns which are injurious to cattle.

One of the major weed problems in arable land in Western Canada is couchgrass (Agropyron repens (L.) Beauv.). This is a rhizomatous species, which accounts for its persistence once it becomes established.

Surveys conducted by weed workers in Alberta (22) and Manitoba (32) indicated 10 and 4 percent, respectively, of the cropped land is infested with couchgrass. Couchgrass is more likely to proliferate when land is cleared or broken than where it is left undisturbed. Once couchgrass becomes established it is very difficult to eradicate. Carder (22) reported that complete eradication of couchgrass is necessary because it costs more to control couchgrass on a yearly basis than to eradicate it.

In 1960 a new chemical, paraquat, was tested for pasture renovation. This herbicide acts mainly as a dessicant on plant tissue but some research on perennial plants treated with paraquat alone or in combination with other herbicides suggests that translocation may also be a factor. Its major advantage over other herbicides appeared to be the absence of chemical residues in the soil.

More information on the usefulness of paraquat under Manitoba conditions would aid in determining whether this herbicide can be used for chemical pasture renovation and control of perennial grassy weeds in this province.

The purpose of this study is to determine whether paraquat followed by forage seeding can successfully convert poor quality low-yielding native pastures into productive pasture and whether paraquat can effectively control perennial grassy weeds.

LITERATURE REVIEW

I. Native Pasture Improvement

Pasture improvement without tillage was first introduced in 1927 by Graber (27) who burnt, fertilized, and then seeded with drought resistant legumes unproductive, unplowable, grub-infested pastures in Wisconsin. Graber recognized that the existing vegetation must be killed or suppressed sufficiently to prevent serious competition with the seeded species and that good soil contact with the seed is a requirement of germination. In 1944, Brown et al. (46) recognized the potential of herbicides as a complete or partial substitute for tillage in suppressing existing vegetation. Satisfactory stands of Ladino clover were obtained by broadcasting seed one year after application of 200 pounds per acre of ammonium thiocyanate or sodium chlorate. In subsequent trials, Brown encountered two serious problems. First, chemical residues remained in the soil resulting in poor seed germination, and second, resident perennial herbs free from competition of grass sod proliferated and exerted extreme competitive pressure on establishing plants.

Over-drilling in which a thin slice of sod is removed in order to increase seed-soil contact thus giving the seedling a better chance of survival was developed by Blackmore (7), in New Zealand. This method failed primarily because the competition from the resident vegetation on the establishing species was too great (9,26). It became apparent that for non-tillage pasture renovation to succeed, some method to remove the competition from the resident vegetation must be found (26).

Peters (46) in 1954 reported that dalapon (sodium 2,2-dichloropropionate) effectively reduced grass competition and allowed legume seedlings to establish but competition from numerous broad-leaved weeds was severe during the seedling year. Dalapon was used in chemical pasture renovation projects with limited success because of one major problem. Seeding of a legume after the application of 7.5 to 10 pounds per acre of dalapon must be delayed 2 to 4 weeks due to chemical residues in the soil (8,46). This delay permitted regrowth of the resident vegetation before a legume could be seeded in the area. As a result, the establishing legume suffered severe competition from the resident vegetation.

In 1962, Jones (40) reported that because there were no chemical residual effects in the soil after application of paraquat (1:1-dimethyl 4:4-bipyridylium) over-sowing could follow immediately after spraying. Subsequently many workers (35,40,53,54,59) demonstrated that paraquat at one pound per acre suppressed grass thus permitting legume establishment. Although paraquat appeared to solve the soil residue problem, which was characteristic of dalapon, it showed some selectivity among grass species. Grass resurgence following paraquat treatment depended on whether the species possessed annual, tiller, stoloniferous or rhizomatous growth habit (27). Under California conditions paraquat controlled annual grasses (30,42); however Matthews (43) reported that this herbicide gave very little control of rhizomatous grass species. It was further noted that broad-leaved weeds increased in abundance following grass suppression with paraquat, exerting a severe competitive effect upon the establishing seedlings (10,33,50,54). Old grass sod contains many viable weed seed which germinate when there is a suppressed grass condition (54). Peters (46), in 1960, reported that

many of the weed species associated with permanent pasture sods were relatively resistant to presently available herbicides. Most of these weed species have the common characteristic of propagating by vegetative means. Peters (46) applied 2,4-D at 4 pounds per acre prior to chemical renovation to control broad-leaved weeds. Yarrow (Achillea millefolium), buttercup (Ranunculus spp.), Canada thistle (Cirsium arvense), and cinquefoil (Potentilla, spp.) appeared resistant to 2,4-D. Elliott (27) obtained a better kill of broad-leaved weeds by repeated spraying at lower rates of 2,4-D, at intervals of a few weeks, and by spraying in consecutive years.

Blackmore (6) reported that under New Zealand conditions seed broadcasted in areas where rainfall was approximately 18 inches per annum failed to germinate satisfactorily. Other workers (8,23) have also demonstrated that adequate rainfall is essential for a good strike when seedlings are establishing. Blackmore (6) reported that overdrilling under low rainfall conditions was strikingly superior to broadcasting. This points out the necessity of the seed being in contact with the soil in low rainfall areas.

Application of nitrogen and phosphate fertilizer is essential to successful legume establishment (10,26,28). Cross and Robinson (26) reported that phosphate should always be sown with the seed. Under conditions when natural grasses respond quickly to fertilizer, delaying the nitrogen application up to 4 or 6 weeks after chemical treatment and forage seeding is advantageous (23,49).

II. Wild Barley Control.

Paraquat has been used to control top growth of wild barley. Vanden Born (55) and Friesen (31) reported that 1 to 2 pounds per acre of paraquat dessicated wild barley but regrowth occurred. McCurdy (44) used paraquat at rates of up to 4 pounds per acre to control wild barley in order to establish tall wheat grass. A group of workers from California and Nevada (30) reported that superior forage establishment occurred when forage seeding was accomplished in the early spring compared to seeding later in the spring and summer.

III. Couchgrass Control.

Herbicides currently recommended for the control of couchgrass in Manitoba and Alberta include dalapon (sodium 2,4-dichloropropionate) applied at 10 to 30 pounds per acre, and TCA (sodium trichloroacetate) at 60 to 100 pounds per acre (3,22). Weed workers (22) in Alberta recommend that tillage methods be used prior to dalapon application and 2 to 3 weeks following dalapon application. Brown (11) found that rates of 40 to 60 pounds per acre of dalapon are required to eradicate couchgrass under Western Manitoba conditions. European workers (4,5,45,56) reported that 8 to 22 pounds per acre of dalapon are required to control couchgrass. Other weed workers (2,16) reported that lower rates of dalapon may be applied initially followed by 2 or 3 retreatments when necessary.

Carder (17) in Alberta recommended that tillage methods follow TCA application when eradicating couchgrass. He reported that TCA gave 99 percent control of couchgrass when applied at 100 pounds per acre. Other workers (24,42,45,47) have demonstrated that TCA applied at 20 to 50 pounds per acre will not give adequate couchgrass control.

Selleck (51,52) reported that complete control of couchgrass resulted from two applications of amitrole-T (3-amine-1,2,4-triazole plus ammonium thiocyanate) at 16 pounds per acre and from 3 applications of amitrole-T, one at 7 pounds per acre plus 2 applications at 6 pounds per acre. However, other weed workers (25,37,38) reported that amitrole-T applied at 4 to 20 pounds per acre will not eradicate couchgrass.

Alban (1) controlled vigorously growing couchgrass by applying MH (1,2-dihydropyridozine, maleic hydrazide) in the early spring or early fall at 15 or 20 pounds per acre. Bula (13) and Carder (14) indicated that MH gave good control of couchgrass during the year of application but couchgrass reinfestation occurred the following year.

Helgason (36) and Carder (15) found that the application of 80 pounds per acre of fenuron (3-phenyl-1,1-dimethylurea) would also control couchgrass. However, when the residual effect of the fenuron was decreased to a level where couchgrass could survive, couchgrass reinvasion was rapid (15).

Another herbicide which has been evaluated for couchgrass control is isocil (5 bromo-3-isopropyl-6-methyluracil). Applications of this chemical at 10 to 30 pounds per acre did not result in good control during the treatment year but gave 100 percent plant kill a year after treatment (21). Recently Gautier (34) found that under conditions in France couchgrass was susceptible to a chemically related herbicide bromacil (5 bromo-3-sec-butyl-6-methyluracil), at 5 to 9 pounds per acre.

Research on the control of couchgrass in Canada has recently centred on paraquat. Carder (18) has reported that applications of paraquat resulted in good initial couchgrass top-growth control but regrowth

occurred within 2 months after application. Paraquat treatment at this time was followed by regrowth after an interval of one month. When the area was rotovated after paraquat retreatment, regrowth still occurred within a month. Jeater and McIlvenny (39) indicated excellent control of top growth was secured by spraying paraquat (1 lb./ac.) alone or in combination with amitrole (5 or 10 lbs./ac.). One year after spraying with paraquat and with paraquat plus low rates of amitrole, some regrowth occurred, while those areas sprayed with paraquat and the higher rates of amitrole were completely killed.

Buchholtz (12) recommended 5 to 6 summer cultivations for couchgrass control. Carder (20) indicated that a rotovator was the best implement to eradicate couchgrass by tillage means. Proctor (48) reported that 3 rotovations at monthly intervals gave fair couchgrass control.

MATERIALS AND METHODS

The experiments described in this report will be discussed under the following headings:

I. Native Pasture Improvement.

II. Wild Barley Control.

III. Couchgrass Control.

I. Native Pasture Improvement

Three separate experiments were conducted during 1964 and 1965:

A. Pasture improvement study, spring 1964.

a) No pre-treatment with phenoxy herbicides.

b) Pre-treatment with phenoxy herbicides.

B. Pasture improvement study, fall 1964.

A. Pasture improvement study, spring 1964.

a) No pre-treatment with phenoxy herbicides.

This experiment was located on an abandoned school yard in the Portage la Prairie area. This area was chosen because of the dominance of blue grass (Poa pratensis L.) which is considered a desirable native pasture grass. Other species in the experimental area included: brome grass (Bromus inermis Leyss.), western snowberry buckbrush (Symphoricarpos occidentalis Hook.), wild prairie rose (Rosa spp.), (Aster lateriflorus (L.) Britt.), smooth aster (Aster Laevis), many flowered aster (Aster pansus (Blake) Conquist), prairie sage (Artemisia gnaphalodes Nutt.), Canadian goldenrod (Solidago canadensis L.) and stiff goldenrod (Solidago rigida L.).

The site had not been grazed for several years prior to chemical treatment and as a result considerable dead vegetation had accumulated. In order to increase seed contact with the soil, this mat was removed by burning on May 14, 1964.

Assessment of the plant vegetation were recorded prior to treatment and at various intervals following treatment using a point quadrat method. Estimates of the percent plant coverage of the ground was recorded for each plant species. Four separate point quadrat counts were recorded per plot from a fixed position within each plot. The 4 counts per plot were averaged to give a single value, expressed as percent coverage for each plant species. The recorded percent coverage of the individual species was grouped into 4 categories: grasses, woody perennials, herbaceous perennials, and alfalfa. Individual members of each category included:

grasses; brome grass, blue grass, alkali cord grass, big bluestem.

woody perennials; western snowberry buckbrush, wild prairie rose.

herbaceous perennials; prairie sage, asters, goldenrods, tall coneflower, narrow leaf sunflower.

alfalfa.

The experimental design on the native pasture consisted of a completely randomized block, replicated four times. Individual plots were 14 feet wide and 30 feet long.

In this experiment alfalfa was seeded on June 23, 1964 and paraquat was applied on June 24, 1964. Alfalfa was seeded at the rate of 7 pounds per acre. A pony press drill with the maximum amount of pressure applied to the discs, was used in seeding the alfalfa to ensure correct seed placement into the sod. A check and 3 rates of paraquat

were included in each replicate. A wetting agent (Agrol 90) was added at the rate of 4 milliliters per gallon to all treatments which contained paraquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre. Fifty pounds per acre of nitrogen and 20 pounds per acre of phosphate were broadcasted uniformly over the area after the alfalfa had been sown. On July 9, 1965 the vegetation was mowed and removed from the entire experimental area.

b) Pre-treatment with phenoxy herbicides

A second experiment initiated during the spring of 1964 was located on the same site. The botanical components in the experimental area were similar to those described under part (a). The mat of dead vegetation which had accumulated over several years was over-burnt. Removal of the dead vegetation mat was considered desirable to permit the legume seed to come in better contact with the soil.

The experimental design consisted of a completely randomized block replicated 4 times. Individual plots were 14 feet wide and 30 feet long. The point quadrat method was used to assess the changes in vegetation prior to and following chemical application.

The entire experimental area was uniformly treated on June 18, 1964 with 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) in the ratio of 2:1 at 24 ounces per acre. Paraquat was applied on June 24, 1964, one day after the seeding of alfalfa. Alfalfa was seeded at 7 pounds per acre with a pony press drill as described in the previous experiment. Fifty pounds per acre of nitrogen and 20 pounds per acre of phosphate were broadcasted uniformly over the area on June 23, 1964. Alfalfa failed to germinate on the experimental area during 1964 and it was suspected that residues from

the phenoxy herbicides had remained in the soil. The failure of alfalfa establishment during 1964 necessitated retreatment with paraquat and reseeding of alfalfa in the spring of 1965. Retreatment with paraquat was made on May 22, 1965, two days after reseeding with alfalfa. A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre.

B. Pasture improvement study, fall 1964.

A third experiment was located in the general area of the abandoned school yard on a blue grass dominant native pasture. The botanical components in the experimental area included: blue grass (Poa pratensis L.), brome grass (Bromus inermis Leyss), alkali cord grass (Spartina gracilis Trin.), big bluestem (Andropogon gerardi Vitmon), western snowberry buckbrush (Symphoricarpos occidentalis Hook.), wild prairie rose (Rosa spp.), (Aster lateriflorus (L.) Britt.), smooth aster (Aster laevis L.), many flowered aster (Aster pansus (Blake) Conquist), prairie sage (Artemisia gnaphalodes Nutt.), Canadian goldenrod (Solidago canadensis L.), stiff goldenrod (Solidago rigida L.), tall coneflower (Rudbeckia laciniata L.), and narrow-leaved sunflower (Helianthus maximilianii Schrad.).

The experimental area was not grazed prior to chemical treatment. The vegetation on the experimental area was mowed and removed from the area in the late fall to reduce the mat of dead vegetation, thus permitting greater seed-soil contact.

The experimental design on the native pasture consisted of a completely randomized block replicated 4 times. Individual plots were 14 feet wide and 30 feet long. Plant assessments were recorded using the point quadrat method as previously described.

Chemical application of paraquat, diquat and dalapon alone, and mixtures of paraquat and diquat were applied on September 13, 1964. A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre. Alfalfa was seeded on May 3, 1965 at 7 pounds per acre. Alfalfa was seeded with a pony press drill as described in the previous experiments. Fertilizer was not applied.

II. Wild Barley Control

Two separate experiments were conducted on wild barley during 1964 and 1965:

A. Evaluation of herbicides to control wild barley.

B. Wild barley control followed by the improvement of the area with a seeded forage crop.

A. Evaluation of herbicides to control wild barley.

The experiment was located near Winnipeg on a dense infestation of wild barley (Hordeum jubatum L.). The experimental design was a randomized block, replicated twice. The individual plot size was 7 feet wide and 40 feet long. Wild barley top-growth control was rated from 0 to 10 where 0 equals no top growth control and 10 equals complete top growth control. Herbicides applied on June 8, 1964 included paraquat, dicamba (2-methoxy-3,6-dichlorobenzoic acid), and diquat (6,7-dihydrodipyrido (1,2-a:2',1'-c) -pyrazidiinium). A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat and diquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre.

B. Wild barley control followed by the improvement of the area with a seeded forage crop.

This project was conducted adjacent to the area described in part A. The experimental design was a split plot replicated twice. Individual plot size was 7 feet wide and 20 feet long.

The experiment carried out in 1965 was designed to further evaluate paraquat for wild barley control. Paraquat was applied on 4 different dates (May 12, May 31, June 15, and June 22) to determine if date of

herbicide application was important for wild barley control.

A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre. Immediately following herbicide application, a wet-land grass mixture was uniformly broadcasted over the area. The mixture consisted of reed canary grass at 3 pounds per acre, meadow fescue at 6 pounds per acre and alsike clover at 2 pounds per acre. Wild barley top growth control was rated 0 to 10 where 0 equals no top growth control and 10 equals complete top growth control. Percent coverage of the seeded forage mixture was estimated using the point quadrat method as outlined in the pasture improvement projects.

III. Couchgrass Control.

Four different experiments are described in this investigation.

A. Evaluation of paraquat and mixtures containing paraquat, to control couchgrass.

B. Evaluation of paraquat and bromacil to control couchgrass.

C. Evaluation of paraquat and rotovation to control couchgrass.

D. Evaluation of fall application of paraquat to control couchgrass.

A. Evaluation of paraquat and mixtures containing paraquat to control couchgrass.

The project was located in the Portage la Prairie area. This area was chosen because of the dense uniform infestation of couchgrass. The experimental design was a completely randomized block replicated four times. Individual plots were 14 feet wide and 30 feet long.

In the first experiment, paraquat alone and mixtures containing paraquat were evaluated. Two additional treatments, dalapon (2,2-dichloropropionic acid) and TCA (trichloroacetic acid), which are presently recommended for couchgrass control, were included in the evaluation trial. Paraquat was applied at one pound per acre alone or in combination with each of 5 other herbicides: amitrole-T (3-amino-1,2,4-triazole plus ammonium thiocyanate), MH (1,2-dihydropyridazine-3,6-dione), fenuron TCA (3-phenyl-1,1-dimethylurea trichloroacetate), isocil (5-bromo-3-isopropyl-6-methyluracil) and varsol. A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat. TCA and dalapon were applied at 60 and 25 pounds per acre respectively. Initial herbicide applications were made on May 22, 1964, when the couchgrass was 4 to 6 inches in height. Since regrowth of couchgrass occurred 6 weeks after the initial treatment, all plots except those treated with TCA and dalapon were retreated on July 7, 1964. Rates were similar to the earlier treatments. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre. Assessments of couchgrass top growth control were recorded at monthly intervals following herbicidal treatment. The 0 to 10 rating system where 0 equals no top growth control and 10 equals complete top growth control was used to estimate the amount of visible couchgrass top growth.

B. Evaluation of paraquat and bromacil to control couchgrass.

This project initiated in 1965 was designed to compare paraquat and bromacil (5-bromo-3-sec-butyl-6-methyluracil) for couchgrass control. The experiment was located in the Portage la Prairie area adjacent to the project discussed in Part A.

The project was designed as a factorial with 4 levels of paraquat and 4 levels of bromacil, replicated 4 times. The individual plot size was 7 feet wide and 30 feet long. Single application of paraquat and bromacil mixtures were applied on May 30, 1965. A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to all treatments which contained paraquat. All herbicides were applied with a small plot sprayer delivering 20 gallons total solution per acre. Assessments of couchgrass top growth control were recorded on three separate intervals using the 0 to 10 rating system.

C. Evaluation of paraquat and rotovation to control couchgrass.

This project was initiated in 1964 to evaluate the effectiveness of paraquat and rotovation alone and in various combinations to control couchgrass. The project was located in the Portage la Prairie area adjacent to the experiment discussed in Part A.

The experimental design was a split plot replicated 4 times. The individual plots were 7 feet wide and 30 feet long. Paraquat applications were made on May 22, 1964 when the couchgrass was 4 to 6 inches in height. This resulted in initial couchgrass suppression but regrowth of the couchgrass occurred in approximately one month to six weeks. Therefore, retreatment with paraquat was made whenever couchgrass regrowth was four inches in height until the couchgrass was completely eradicated. Similarly, combinations of rotovation and paraquat were begun on May 22, 1964 with a paraquat application followed by rotovation when couchgrass regrowth was 4 inches in height. Alternate paraquat treatments and rotvations were carried out until the couchgrass was eradicated. A wetting agent (Agrol 90) was added at the rate of 4 millileters per gallon to

all treatments which contained paraquat. All herbicides were applied with a small plot sprayer, delivering 20 gallons total solution per acre. The treatment which consisted of rotovation alone was first made on May 22, 1964 followed by further rotovations whenever the couchgrass reached 4 inches in height. A rotovation treatment consisted of 3 trips over the area at a depth of 3 inches with a 24-inch Howard rotovator. Assessments of couchgrass top growth control were recorded using the 0 to 10 rating system. Assessments were recorded approximately 30 days after the initial treatment and subsequent treatments.

D. Evaluation of fall application of paraquat to control couchgrass.

The experiment was initiated in 1964 to evaluate the effectiveness of fall applications of paraquat to control couchgrass. This experiment was located in the same field as the previously described experiments.

The experimental design was a completely randomized block replicated 4 times. The size of the individual plots were 14 feet wide and 30 feet long.

Paraquat treatments were applied in the fall of 1964 in an effort to control couchgrass the following spring. The couchgrass was mowed in late summer and couchgrass growth was 6 to 7 inches in height when paraquat was applied on September 14, 1964. A wetting agent (Agrol 90) was added at the rate of 4 milliliters per gallon to the paraquat treatments. Paraquat was applied with a small plot sprayer, delivering 20 gallons total solution per acre. Assessments of couchgrass top growth control were recorded using the 0 to 10 rating system, on three separate occasions following treatment.

METEOROLOGICAL DATA

Meteorological data for Portage la Prairie was recorded by the Meteorological Division, Department of Transport. Data for 1964 and 1965 are appended (Appendix 1).

Temperatures for the 1964 growing season were below normal for the months of June, August, and September, but above normal for the months of April, May, and July. Temperatures in 1965 were below normal for all months except April and June, when temperatures were above normal.

Precipitation for the 1964 growing season was well above normal for the months of June, July, and August, but below normal for April, May, and September. In 1965, the precipitation was above normal for May, July, and September, and below normal for July and August.

RESULTS AND DISCUSSIONS

I. Native Pasture Improvement

A. Pasture improvement study, spring 1964.

a) No pretreatment with phenoxy herbicides

The effectiveness of paraquat in suppressing total vegetation in the pasture improvement project may be determined from the data in Table 1.

Table 1 - Total plant coverage in paraquat treated plots, spring pasture project, 1964-1965.

Treatment		Total Plant Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	54.9	45.8**	61.1*	48.8*	61.5	66.8
Paraquat	1/2	54.7	41.7**	59.7**	49.7**	61.0	68.6
Paraquat	1	56.1	30.7**	55.4**	52.5**	63.1	70.4
Check	0	52.5	59.2	68.8	42.8	61.7	63.9
		NS				NS	NS
LSD 5%			8.9	5.8	4.5		
LSD 1%			12.8	8.1	6.3		
CV %		8.3	12.8	6.4	6.3	4.4	8.9

In this and subsequent tables the following symbols denote:

*	significant at the 5% level of probability.
**	significant at the 1% level of probability.
NS	non-significant differences.
LSD 5%	least significant difference at the 5% level.
LSD 1%	least significant difference at the 1% level.
CV	coefficient of variability.
a	alfalfa cover could not be measured at this time.
b	0-10 rating system (0=no top growth control; 10=complete top-growth control).

Plant coverage when estimated as a percentage provides a distribution which is not normal but skewed. The original results (Appendix 2) were transformed using the arcsin transformation and transformed data are used throughout this discussion. Total plant coverage recorded prior to treatment on June 24, 1964 indicated that the area was uniform. Results recorded on July 14, 1964 indicated that the total plant coverage decreased as the rate of paraquat increased from 1/4 to one pound per acre. On May 19, 1965, eleven months after paraquat treatment, the total vegetation in the paraquat-treated plots was significantly larger than in the untreated plot. Similarly, no significant differences in total plant coverage could be detected on June 22, 1965 and August 16, 1965, indicating that paraquat-tested plots had completely recovered one year or less after treatment.

Grass coverage on 6 dates during 1964 and 1965 are presented in Table 2.

Table 2 - Coverage of grass components in paraquat-treated plots, spring pasture project, 1964-1965.

Treatment		Grass Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	45.8	39.3	42.7	43.9	45.3	45.7
Paraquat	1/2	43.7	31.8*	37.3	46.4	43.5	42.8
Paraquat	1	41.7	25.0**	32.9	43.7	36.6	40.9
Check	0	44.1	43.9	44.4	40.7	46.4	48.9
		NS		NS	NS	NS	NS
LSD 5%			11.7				
LSD 1%			16.8				
CV%		9.2	21.0	21.7	7.7	12.7	22.4

The data for June 15, 1964 indicated that for this component the area was uniform prior to treatment. Grass suppression following treatment on June 24 increased as rates of paraquat increased from 1/4 to one pound per acre. Significant differences (P.05) in grass coverage were detected for the 1/2 and one pound rate. Grass components recovered rapidly following paraquat treatment and differences between paraquat treatments appeared non-significant at the end of the first year (August 12, 1964) and during the second year (May 19, 1965; June 22, 1965; August 16, 1965).

Paraquat application did not result in significant suppression of the woody perennials during the treatment year. Data for woody perennials recorded on 6 dates during 1964 and 1965 are presented in Table 3.

Table 3 - Coverage of woody perennials in paraquat treated plots, spring pasture project, 1964-1965.

Treatment		Woody Perennial Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	6.5	7.5	13.6	11.1	16.1	8.6
Paraquat	1/2	8.5	8.8	18.9	8.3	18.5	14.8
Paraquat	1	8.1	10.6	17.0	11.0	20.1	10.4
Check	0	6.6	8.6	13.6	8.8	19.7	12.8
		NS	NS	NS	NS	NS	NS
CV%		57.3	59.3	43.9	29.1	47.2	63.9

One pound per acre of paraquat resulted in little suppression of the woody perennials 20 days (July 14, 1964) after chemical application. However, although paraquat treatments resulted in immediate defoliation of wild prairie rose, this perennial recovered and produced new growth within 3 weeks after herbicide application. Results indicate that the population of woody perennials increased irrespective of treatment.

Smaller values for the woody perennials were recorded on August 16, 1965 because the experimental area was clipped on July 9, 1965.

Data presented in Table 4 indicated that paraquat treatment of a uniform area resulted in reduction in herbaceous perennial coverage.

Table 4 - Coverage of herbaceous perennials in paraquat treated plots, spring pasture project, 1964-1965.

Treatment		Herbaceous Perennial Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	24.4	14.2*	23.6	4.2	15.5	16.6
Paraquat	1/2	21.6	21.0	26.8	6.3	18.6	15.5
Paraquat	1	27.3	9.5**	18.4	6.8	11.5	9.9
Check	0	19.4	26.2	32.6	2.4	18.9	21.5
		NS		NS	NS	NS	NS
LSD 5%			9.6				
LSD 1%			13.9				
CV%		30.2	34.1	26.1	58.9	39.9	52.0

Specifically, it may be noted that by July 14, 1964 paraquat applied at 1/4 and one pound per acre had significantly reduced the coverage. No significant differences in the treatments could be detected in the assessments recorded in the fall of the treatment year (August 12, 1964) and during the second year (May 19, 1965; June 22, 1965; August 16, 1965).

The distribution of the major components of the herbaceous perennials are individually separated in Figure 1, 2 and 3 for paraquat at one pound per acre and the natural check. The population of prairie sage was greatly decreased during the year of chemical application and remained at this low level the following year (Figure 1). Similarly, the plant population of asters (Figure 2) was decreased following application of paraquat and remained at a low level the following year. It appears

that good initial suppression of these herbaceous plants occurred immediately after paraquat treatment and they remained at a low level due to plant competition. The population of prairie sage and aster was further reduced by the clipping of the experimental area on July 9, 1965. The decrease in population of the goldenrods following paraquat treatment was similar to that noted for prairie sage and asters. However, once the experimental area was clipped on July 9, 1965, the population of the goldenrods increased. It would appear that in this instance the clipping of the experimental area removed the plant competition, resulting in an increase in the goldenrod population.

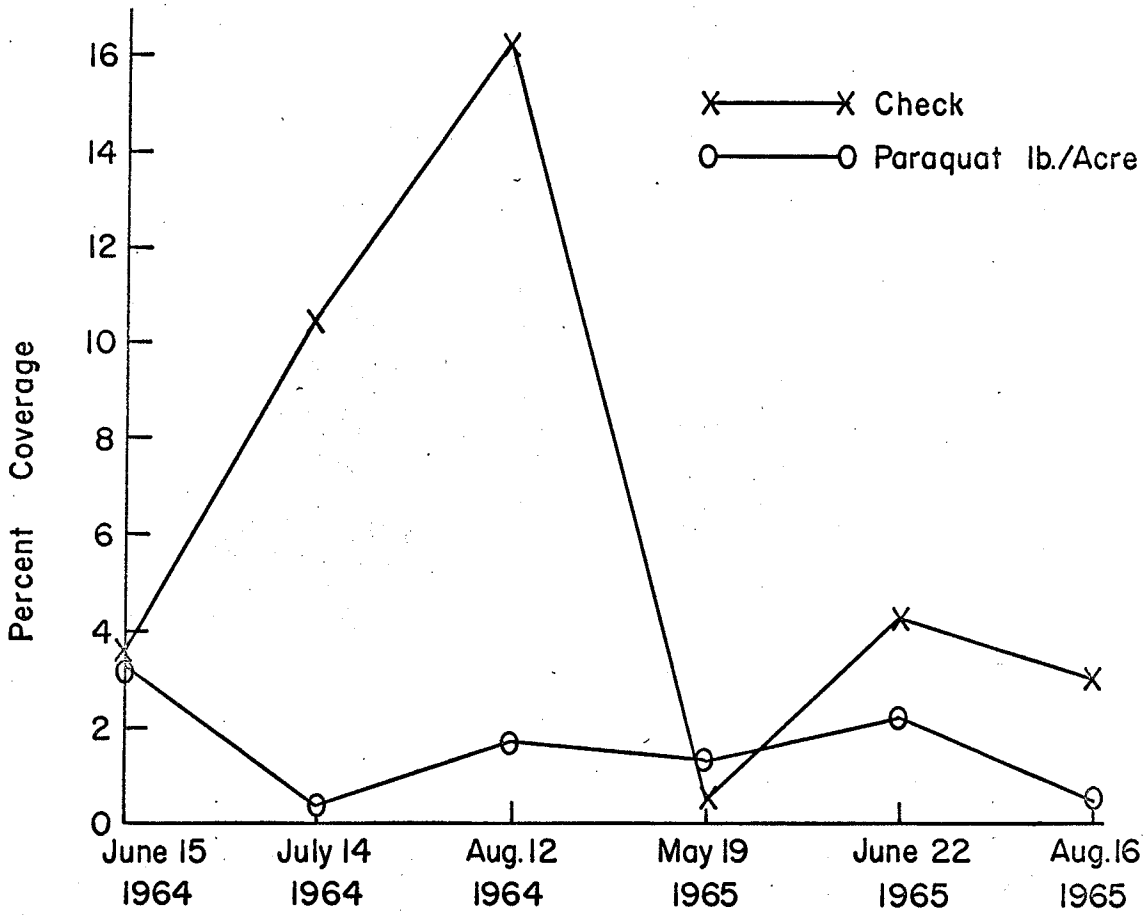

Figure 1 Coverage of Prairie Sage in the Pasture Improvement Project, Spring 1964.

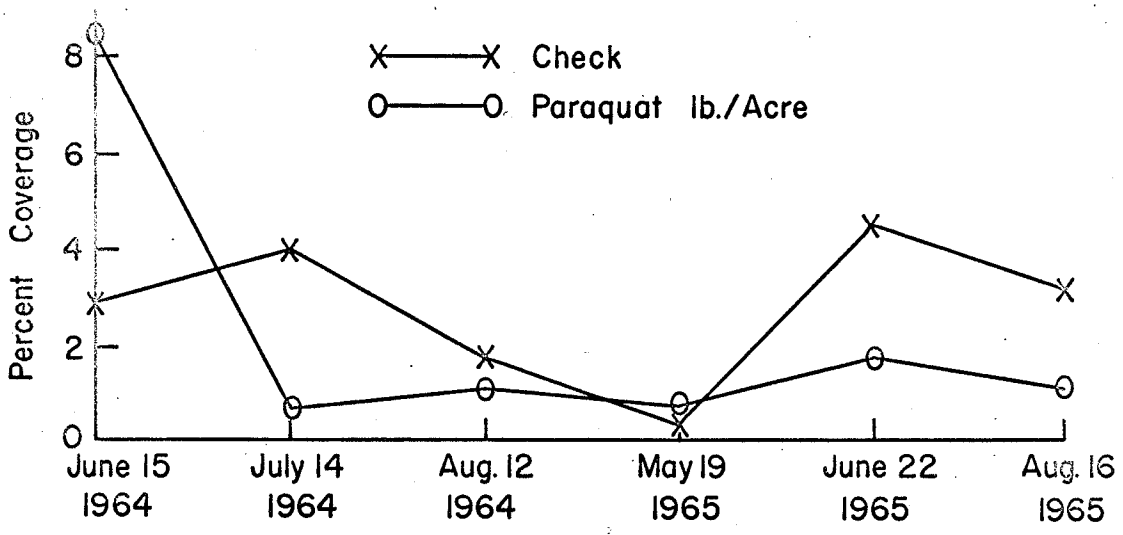

Figure 2 Coverage of Asters in the Pasture Improvement Project, Spring 1964.

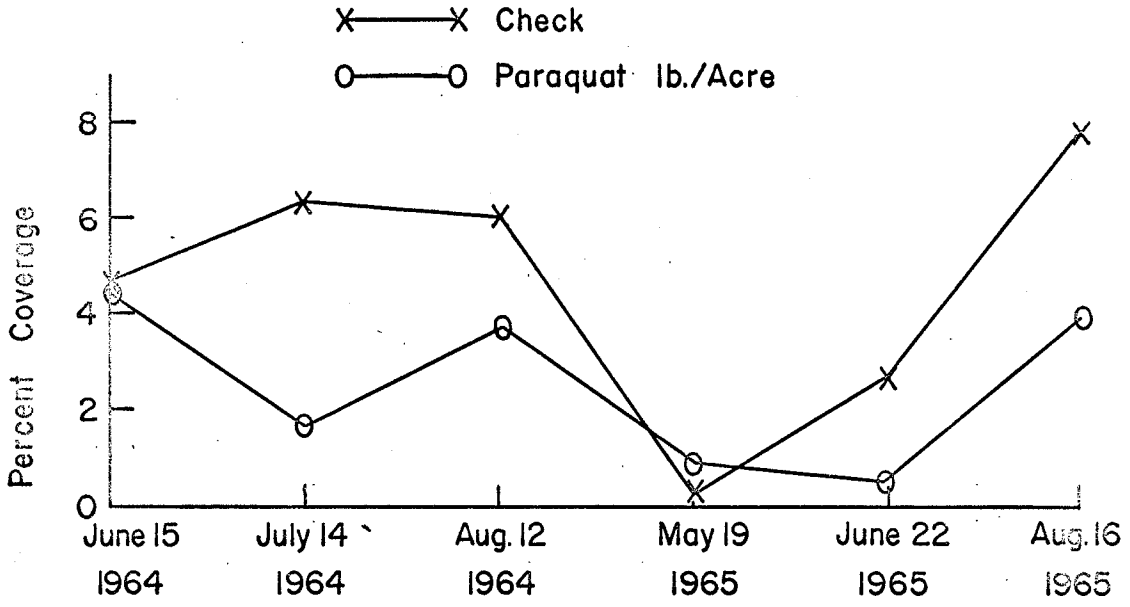

Figure 3 Coverage of Goldenrods in the Pasture Improvement Project, Spring 1964.

The effectiveness of paraquat in suppressing resident vegetation and thus permitting sod-seeded alfalfa to become established may be detected in Table 5, and from Plates 1 and 2.

Table 5 - Coverage of alfalfa in paraquat treated plots, spring pasture project, 1964-1965.

Treatment		Alfalfa Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	-[a]	-	4.9	4.2	8.0	15.6
Paraquat	1/2	-	-	11.7	4.9	10.1	25.1
Paraquat	1	-	-	20.6*	13.0	24.7	43.1*
Check	0	-	-	2.2	-	-	-
					NS	NS	
LSD 5%				12.5			31.8
CV %				85.3	128.2	113.0	101.4

Alfalfa did not measurably contribute to coverage on the first two assessments. Significant amounts of alfalfa had become established by August 12, 1964 on the plots treated with one pound per acre of paraquat. Alfalfa establishment was further enhanced by clipping the experimental area on July 9, 1965 so that by August 16, 1965 almost one half of the coverage was alfalfa. Alfalfa coverage increased as the rates of paraquat increased from 1/4 to one pound per acre. The linear relationship between the increasing rates of paraquat and increasing alfalfa cover is apparent, but due to high variability within the project additional work is required before making specific recommendations.

Plate 1. Check plot, two years after alfalfa was seeded.

Plate 2. Alfalfa establishment two years after treatment with paraquat (1 lb/ac.) and alfalfa was seeded.

A measure of the overall value of paraquat treatment in improving native pasture may be obtained from Figure 4. This figure illustrated differences which were present at the conclusion of the experiment in the plots receiving the various treatments. The application of paraquat had resulted in substantial changes in the botanical composition. Herbaceous perennials and grasses decreased in content as the rate of paraquat applied had increased. However, woody perennials were unaffected by paraquat treatments up to one pound per acre. Despite this the coverage of alfalfa increased directly as the rate of paraquat applied increased and at the one pound per acre rate alfalfa was contributing significantly to native pasture improvement.

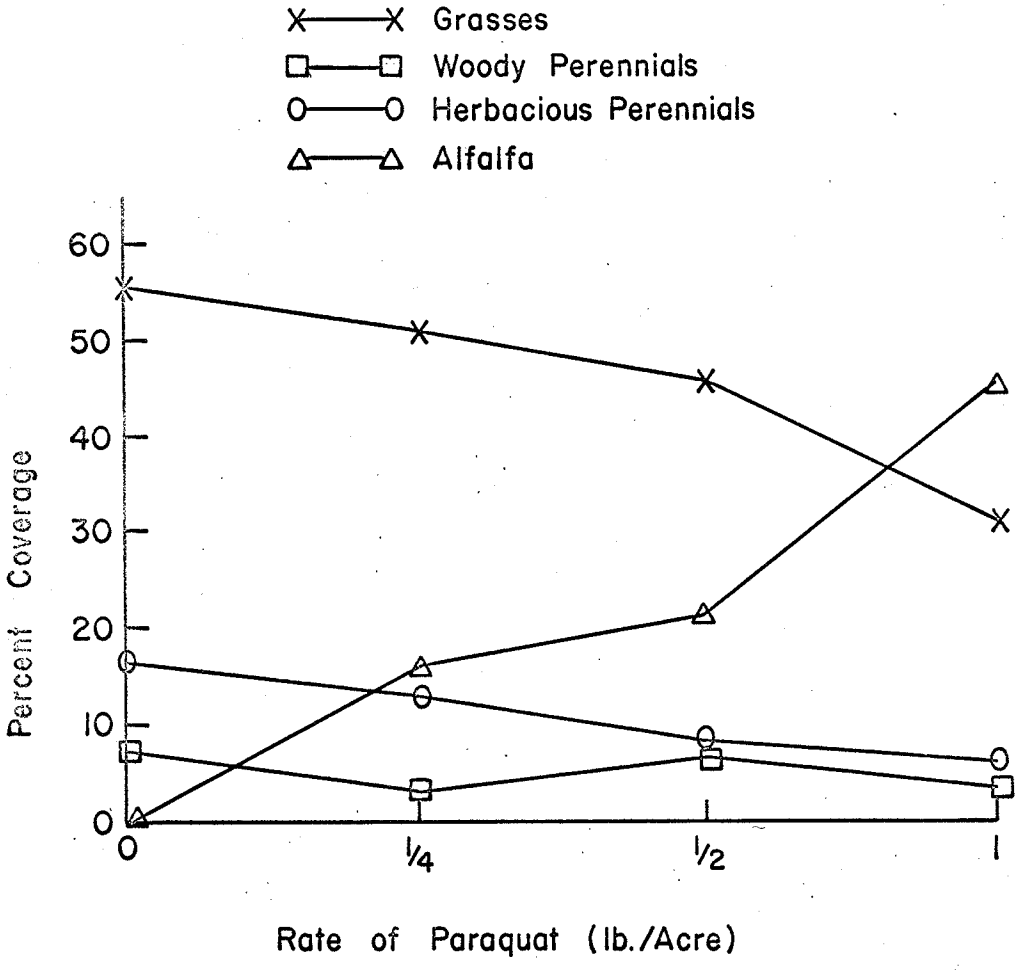

Figure 4 Effect of Paraquat on the Plant Population Two Years After Spring Treatment 1964.

b) Pre-treatment with phenoxy herbicides

A mixture of 2,4-D:2,4,5-T applied at 24 ounces per acre to control broad-leaved weeds prior to paraquat and sod-seeding treatments resulted in fair control of herbaceous perennials but was not adequate to control woody perennials. Application of paraquat (Table 6) resulted in effective suppression of the total plant coverage in the pre-treated spring pasture improvement project.

Table 6 - Total plant coverage in the 2,4-D:2,4,5-T pre-treated spring pasture improvement project, 1964-1965.

Treatment		Total Plant Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	62.6	33.5**	57.4**	48.9	49.0**	61.4
Paraquat	1/2	63.2	26.9**	57.9**	46.7	42.7**	59.3
Paraquat	1	62.3	21.8**	56.5**	48.8	40.8**	67.2
Check	0	63.5	52.7	66.4	44.5	59.4	61.3
		NS			NS		NS
LSD 5%			8.8	4.7		6.8	
LSD 1%			12.7	6.7		9.7	
CV%		3.8	16.4	5.0	9.3	8.8	13.1

An analysis of the total plant coverage prior to treatment with paraquat on June 24, 1964 indicated that the area was reasonably uniform. Plant assessments recorded on July 14, 1964 and August 12, 1964 for paraquat treated plots were significantly lower than for the untreated area. It would appear that following treatment as the rate of paraquat increased from 1/4 to one pound per acre the total plant coverage decreased. However, by May 19, 1965 no significant differences could be detected between any of the treated plots and the check due to vigorous and complete regrowth. On June 22, 1965, one month after retreatment with paraquat significant decreases in total plant coverage were noted. However, the beneficial effect of paraquat on plant suppression was obscured by the

Clipping treatment over the entire area on July 9, 1965 and, therefore, by August 16, 1965 all plots had comparable total plant coverage.

Data for the grass components assessed on 6 dates during 1964 and 1965 in the 2,4-D:2,4,5-T pre-treatment spring pasture improvement project are presented in Table 7. Analysis of the contribution of grass to coverage prior to treatment indicated that the experimental plots were comparable for this component.

Table 7 - Coverage of the grass components in the 2,4-D:2,4,5-T pre-treated spring pasture project, 1964-1965.

Treatment		Grass Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	47.7	29.4**	46.2*	47.7	41.1**	47.8
Paraquat	1/2	50.5	21.4**	47.0*	45.1	29.2**	41.6
Paraquat	1	47.2	17.1**	41.0**	47.4	25.9**	41.8
Check	0	46.9	50.7	58.1	43.2	49.4	52.3
		NS			NS		NS
LSD 5%			4.1	8.3		4.8	
LSD 1%			6.0	12.0		7.0	
CV %		8.1	8.8	10.9	8.1	8.2	12.0

The grass components were reduced significantly on July 14, 1964 and August 12, 1964 following paraquat application of 1/4, 1/2 and one pound per acre, and on June 22, 1965 following paraquat retreatment at the same rates. As the rate of paraquat increased from 1/4 to one pound per acre the coverage of the grasses decreased. In this, as in the preceding discussion, failure to detect significant differences on May 19, 1965 and August 16, 1965 dates may be attributed to regrowth and clipping, respectively.

Plate 3. Plots treated with paraquat showing the scorching effect of the herbicide.

Plate 4. Plot treated with 2,4-D:2,4,5-T showing the ineffective control of woody perennials.

Application of 2,4-D:2,4,5-T prior to paraquat treatments did not effectively reduce infestations of woody perennials. This is illustrated in Plate 4. Data for the woody perennials assessed on 6 dates during 1964 and 1965 in the 2,4-D:2,4,5-T pre-treatment spring pasture improvement project are presented in Table 8.

Table 8 - Coverage of woody perennials in the 2,4-D:2,4,5-T pre-treated spring pasture project, 1964-1965

Treatment		Woody Perennial Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	6.4	7.0	18.8	3.8	16.8	20.1
Paraquat	1/2	6.0	6.2	15.1	5.6	17.6	20.7
Paraquat	1	5.1	8.3	20.2	6.9	18.3	23.2
Check	0	10.0	7.9	12.8	7.8	21.1	19.6
		NS	NS	NS	NS	NS	NS
CV %		51.5	89.0	54.2	79.9	32.2	36.7

Differences between paraquat treatments recorded during 1964 and 1965 were non-significant. The plant assessments indicate a greater increase in woody perennials when treated with 2,4-D:2,4,5-T followed by paraquat than with 2,4-D:2,4,5-T applied alone. A comparison of the increase in woody perennials from the beginning of the experiment (June 15, 1964) to the end of the experiment (August 16, 1965) indicated a fourfold increase in woody perennials when paraquat at one pound per acre is applied compared to only a twofold increase in the check plot. While these differences were not significant, it may be theorized that woody perennials increased after paraquat treatment because the plant competition which prevents the perennials to make rapid regrowth was reduced.

The herbaceous perennial coverage prior to and following pre-treatment with phenoxy herbicides and paraquat treatments is presented in Table 9.

Table 9 - Coverage of herbaceous perennials in the 2,4-D:2,4,5-T pre-treated spring pasture project, 1964-1965.

Treatment		Herbaceous Perennial Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	27.9	8.8	13.3	6.0	10.1	13.6
Paraquat	1/2	25.4	9.1	13.7	3.7	17.2	16.9
Paraquat	1	28.2	6.8	14.3	2.9	15.2	17.3
Check	0	28.9	4.7	11.7	3.2	12.8	8.0
		NS	NS	NS	NS	NS	NS
CV%		14.1	102.7	68.8	111.4	50.6	30.0

Although the influence of the phenoxy herbicides cannot be obtained directly from the figures in this table, an indirect assessment may be made by comparing the check plot prior to pre-treatment (28.9) with the check plot following pre-treatment (4.7). From these figures it may be concluded that the phenoxy herbicides effectively reduced the herbaceous perennial coverage. An analysis of coverage prior to treatment failed to detect significant differences between plots in the experimental area. If pre-treatment can be assumed to be uniform then reduction in coverage at subsequent dates cannot be attributed to paraquat treatment. This experiment could not detect significant differences between check and paraquat treated plots.

Data for the establishment of alfalfa in the native pasture pre-treated with 2,4-D:2,4,5-T prior to paraquat are presented in Table 10.

Table 10 - Coverage of alfalfa in the 2,4-D:2,4,5-T pre-treated spring pasture project, 1964-1965.

Treatment		Alfalfa Coverage					
Herbicide	Rate lb/ac	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Paraquat	1/4	-[a]	-	2.3	-	-	6.2
Paraquat	1/2	-	-	5.1	-	4.5	14.9**
Paraquat	1	-	-	9.5	2.8	-	21.4**
Check	0	-	-	-	-	-	-
				NS			
LSD 5%							7.2
LSD 1%							10.3
CV%							42.5

Establishment of alfalfa was satisfactory in the native pasture following 2,4-D:2,4,5-T pre-treatment one year prior to paraquat and sod-seeding treatments.

Differences between paraquat treatments assessed on August 12, 1964 were non-significant, indicating inadequate establishment of alfalfa. Re-treatment with paraquat and reseeding with alfalfa in 1965 resulted in significant increase in alfalfa on August 16, 1965, in the plots treated with paraquat at 1/2 and one pound per acre. Alfalfa content increased as the paraquat rate increased from 1/4 to one pound per acre. The entire 2,4-D:2,4,5-T pre-treated spring pasture improvement project was clipped above the establishing alfalfa seedlings on July 9, 1965 to remove some of the plant competition. This resulted in more vigorous and healthy alfalfa plants in the fall of the retreatment year.

The effect of the 2,4-D:2,4,5-T and paraquat on the botanical composition of the native pasture is recorded in Figure 5. Increasing rates of paraquat resulted in a slight but non-significant increase in the woody perennials and herbaceous perennial coverage.

Grass coverage decreased significantly with paraquat application, but the degree and the permanency of this suppression was influenced by management. Alfalfa, seeded one year after treatment with phenoxy herbicides, was present in inverse proportion to the amount of grass present and, consequently, the highest alfalfa coverage was obtained from plots treated with the highest rate of paraquat.

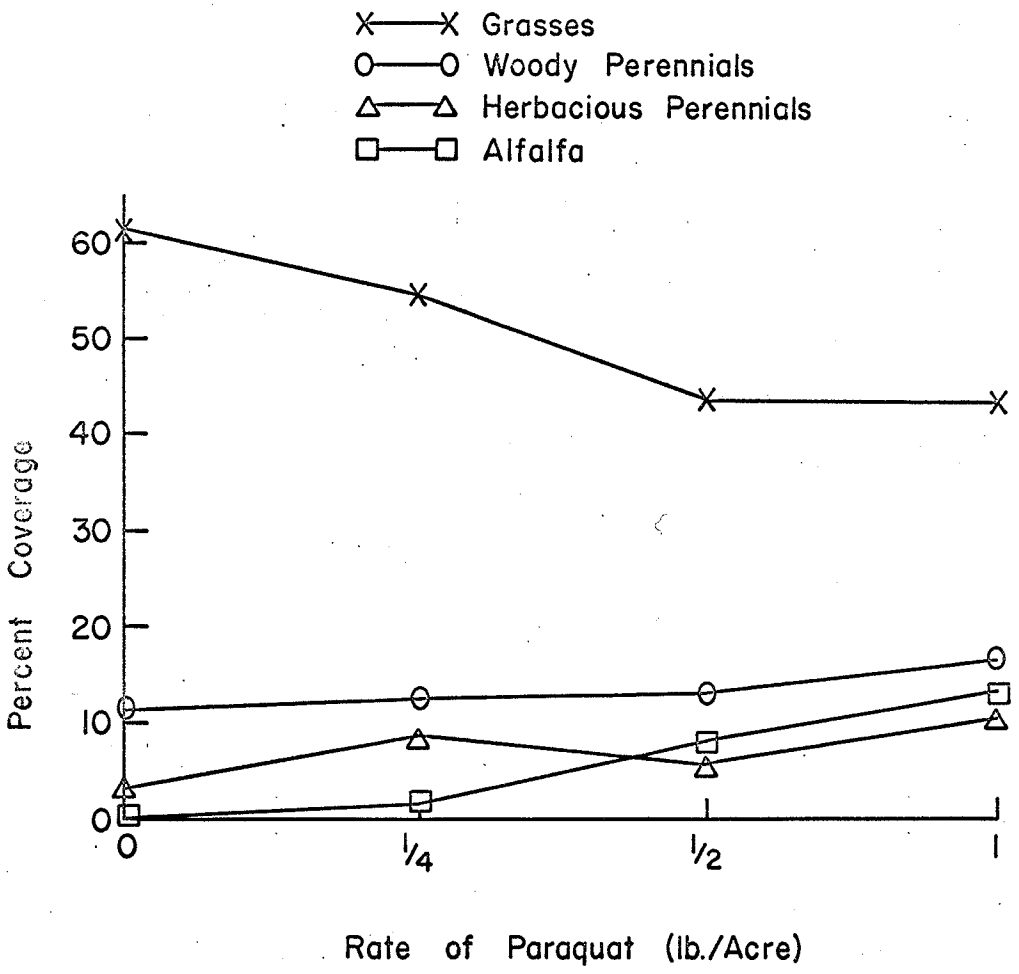

Figure 5 Effect of Paraquat and 2,4-D:2,4,5-T Treatments on the Plant Population Two Years After Initial Treatment.

B. Pasture improvement study, fall 1964.

Dalapon, paraquat, diquat, and mixtures containing paraquat and diquat were applied in the fall of 1964 to suppress the resident vegetation the following spring. Data for the total plant coverage assessed on four dates during 1964 and 1965 are presented in Table 11.

Table 11 - Total plant coverage in the fall pasture improvement project, 1964-1965.

Treatment		Total Plant Coverage			
Herbicide	Rate lb/ac	Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Paraquat	1/2	78.4	45.8	52.1	56.3
Paraquat	1	74.7	45.7	57.1	57.2
Paraquat	1-1/2	80.7	44.4	55.6	60.3
Paraquat + Diquat	1/4 and 1/4	77.0	46.8	52.0	55.1
Paraquat + Diquat	1/2 and 1/2	75.5	48.4	55.0	56.2
Paraquat + Diquat	3/4 and 3/4	79.1	43.7	57.3	58.8
Dalapon	4	79.0	36.4*	61.6	62.6
Check		76.5	47.4	56.1	59.3
		NS		NS	NS
LSD 5%			6.1		
CV%		7.7	9.3	8.6	8.6

Difference between plots in total plant coverage prior to herbicide application on September 12, 1964 were non-significant. Of all treatments, only dalapon resulted in significant reduction in the total plant coverage on June 9, 1965. The plants recovered rapidly and no significant differences between treatments could be detected at the two later dates.

The influence of dalapon on grass coverage may be determined from the data presented in Table 12.

Table 12. - Coverage of grasses in the fall pasture improvement project, 1964-1965.

Treatment Herbicide	Rate lb/ac	Grass Coverage Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Paraquat	1/2	47.6	34.7	31.6	32.0
Paraquat	1	46.8	36.4	32.0	32.0
Paraquat	1-1/2	45.0	32.1	29.8	32.9
Paraquat + Diquat	1/4 and 1/4	45.6	36.1	33.1	33.6
Paraquat + Diquat	1/2 and 1/2	46.7	38.9	32.6	33.8
Paraquat + Diquat	3/4 and 3/4	44.2	34.0	32.9	32.0
Dalapon	4	44.4	25.7*	25.4*	28.7
Check		46.2	35.8	32.5	31.3
		NS			NS
LSD 5%			6.1	4.7	
CV%		6.9	12.3	10.3	16.6

Only dalapon of the 7 chemical treatments significantly reduced grass coverage. This suppression was noted on June 9, 1965 and persisted through to the July 15, 1965 reading. By August 18, 1965 only a slight, non-significant difference could be detected between this and the remaining treatments in the experiment.

Paraquat and mixtures containing paraquat had little effect on the population of woody perennials in the fall improvement project. Data of the assessments of the woody perennials recorded prior to treatment and at various intervals following treatment are presented in Table 13.

Table 13 - Coverage of woody perennials in the fall pasture improvement project, 1964-1965.

Treatment		Woody Perennial Coverage			
Herbicide	Rate lb/ac	Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Paraquat	1/2	8.8	6.0	13.0	13.8
Paraquat	1	5.6	8.0	13.6	14.2
Paraquat	1-1/2	10.4	11.0	16.6	16.7
Paraquat + Diquat	1/4 and 1/4	4.5	6.1	9.7	8.9
Paraquat + Diquat	1/2 and 1/2	4.1	3.8	11.8	12.4
Paraquat + Diquat	3/4 and 3/4	11.4	10.1	14.9	16.5
Dalapon	4	9.8	13.6	16.5	18.0
Check		8.6	9.1	14.6	13.2
		NS	NS	NS	NS
CV%		85.1	65.3	63.8	57.5

Differences between treatments at all dates were non-significant. This indicates that application of paraquat did not effectively reduce the population of woody perennials.

Paraquat and mixtures containing paraquat applied in the fall did not reduce the population of herbaceous perennials (Table 14).

Table 14 - Coverage of herbaceous perennials in the fall pasture improvement project, 1964-1965.

Treatment Herbicide	Rate lb/ac	Herbaceous Perennial Coverage Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Paraquat	1/2	22.2	23.5	29.7	29.6
Paraquat	1	22.4	20.5	32.8	29.7
Paraquat	1-1/2	25.3	23.0	33.1	33.1
Paraquat Diquat	1/4 and 1/4	26.9	24.1	31.1	32.4
Paraquat Diquat	1/2 and 1/2	24.8	23.0	33.7	32.2
Paraquat Diquat	3/4 and 3/4	23.6	21.9	31.3	28.6
Dalapon	4	24.8	18.7	40.2	38.8
Check		21.7	23.5	32.2	35.0
		NS	NS	NS	NS
CV%		22.8	18.5	15.5	13.8

Differences between treatments at all dates were non-significant. This indicates paraquat was relatively ineffective in reducing the population of herbaceous perennials.

Paraquat, diquat and dalapon did not suppress plant growth sufficiently to permit alfalfa establishment (Table 15).

Table 15 - Coverage of alfalfa in the fall pasture improvement project, 1964-1965

Treatment		Alfalfa Coverage			
Herbicide	Rate lb/ac	Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Paraquat	1/2	-[a]	-	7.3	15.7
Paraquat	1	-	-	10.4	15.8
Paraquat	1-1/2	-	-	9.0	12.4
Paraquat Diquat	1/4 and 1/4	-	-	8.7	13.2
Paraquat Diquat	1/2 and 1/2	-	-	6.3	9.6
Paraquat Diquat	3/4 and 3/4	-	-	11.9	20.0
Dalapon	4	-	-	7.6	14.0
Check		-	-	8.2	14.1
				NS	NS
CV%				48.8	31.9

Alfalfa establishment following paraquat, diquat and dalapon treatments was not significantly different from the check. Paraquat and mixtures containing paraquat were ineffective in reducing the resident vegetation to permit alfalfa establishment.

The effect of paraquat on the pasture components one year after fall application is presented graphically in Figure 6. This figure supports the data presented previously which shows that increased rates of paraquat did not change significantly the composition of the grasses, woody perennials, herbaceous perennials, and alfalfa components in the pasture.

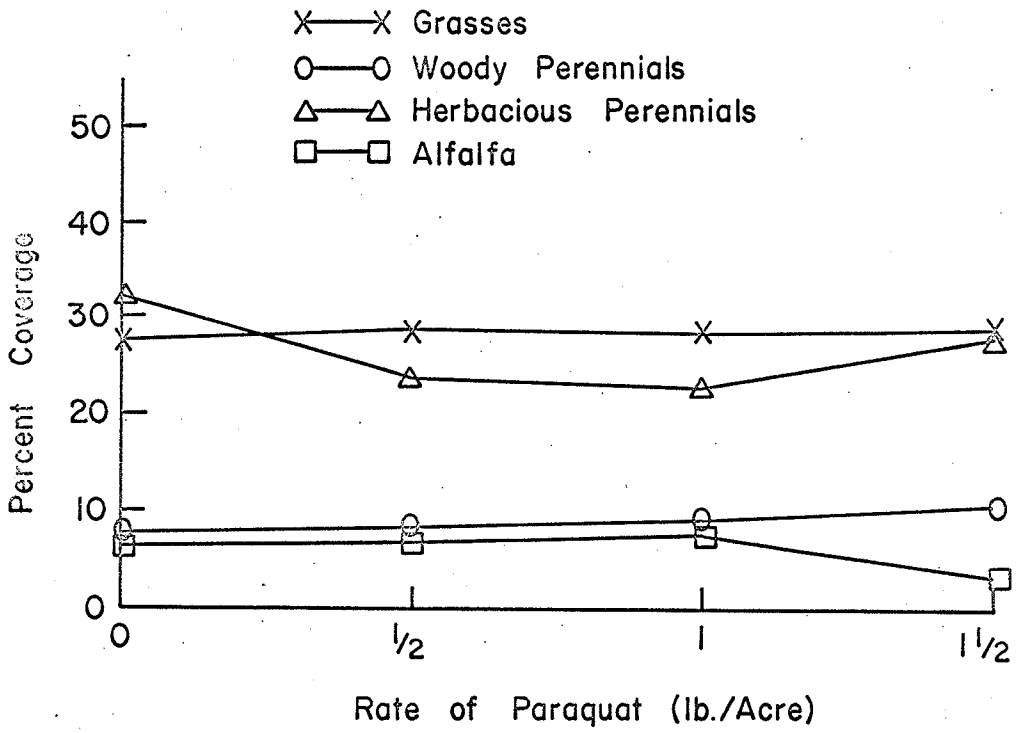

Figure 6 Effect of Paraquat on the Plant Population One Year After Fall Treatment in 1964.

II. WILD BARLEY CONTROL

A. Evaluation of herbicides to control wild barley

Good control of wild barley was obtained with paraquat application, particularly the rates above one pound per acre (Table 16). As the rate of paraquat increased from 8 to 32 ounces per acre the control of wild barley increased. Diquat and dicamba were relatively ineffective for wild barley control.

Table 16 - Evaluation of herbicides for wild barley control

Treatment Herbicide	Rate oz/ac	Wild Barley Top Growth Control July 13, 1965
Paraquat	8	6.5[b]
Paraquat	16	8.5
Paraquat	32	9.0
Diquat	8	2.0
Diquat	16	3.0
Dicamba	8	0.0
Dicamba	12	0.0
Check		0.0

B. Wild barley followed by improvement of the area with a seeded forage crop.

Paraquat applied on wild barley at various rates and on various dates in 1965 resulted in suppression rather than control. Data are presented in Table 17.

Table 17. - Effect of paraquat on wild barley

Treatment			Wild Barley Top-growth Control			
Herbicide	Rate oz/ac	Dates of Application	May 31 1965	June 21 1965	June 29 1965	July 26 1965
Paraquat	8	May 12	6.8[b]	4.0	2.0	0.5
Paraquat	16	May 12	8.5	4.0	3.0	0.5
Paraquat	8	May 31		3.0	2.0	0.0
Paraquat	16	May 31		6.0	3.5	2.5
Paraquat	8	June 15		8.5	8.2	3.0
Paraquat	16	June 15		9.0	9.0	5.0
Paraquat	8	June 29				5.0
Paraquat	16	June 29				6.5
Check			0.0	0.0	0.0	0.0

Regardless of the date of paraquat application regrowth of wild barley occurred. A higher rate of paraquat resulted in better initial wild barley suppression as well as suppression for a longer period during the summer. There does not appear to be a critical date when paraquat can be applied to control wild barley.

Significant establishment of alsike clover occurred when chemical treatments followed by broadcasting of the forage mixture was done during the month of May (Table 18). The fact that the forage mixture was broadcast over the area, coupled with inadequate rainfall for such seeding, may explain why reed canary grass and meadow fescue at all dates and alsike clover at the June dates failed to become established. Date rather than rate of paraquat application was significant in alsike clover establishment. Adequate stands of alsike clover were obtained in areas infested with wild barley following early paraquat application and forage seeding.

Table 18 - Establishment of alsike clover following paraquat treatment.

Treatment Herbicide	Rate oz/ac	Date of Application	Alsike Clover Coverage
Paraquat	8	May 12	15.9**
Paraquat	16	May 12	12.0*
Paraquat	8	May 31	11.6*
Paraquat	16	May 31	32.2**
Paraquat	8	June 15	2.5
Paraquat	16	June 15	1.9
Paraquat	8	June 29	0.6
Paraquat	16	June 29	0.6
Check			0.0
LSD 5%			9.0
LSD 1%			12.9

III. COUCHGRASS CONTROL

A. Evaluation of paraquat and paraquat mixtures to control couchgrass.

Of the 8 herbicides and herbicidal mixtures evaluated for couchgrass control, only one mixture, paraquat and isocil, resulted in effective couchgrass control (Table 19). The effective couchgrass control with paraquat and isocil is illustrated in Plate 5.

Table 19 - Herbicide evaluation trial for couchgrass control.

Treatments				Couchgrass Top-growth Control		
Herbicide	Rate lb/ac	Herbicide	Rate lb/ac	July 7 1964	Aug. 6 1964	Sept. 14 1964
Paraquat	1			3.0[b]	3.7	0.0
Paraquat	1	plus Fenuron TCA	1	4.1	5.3	0.0
Paraquat	1	" Isocil	1	4.9	8.7	9.5
Paraquat	1	" Amitrole-T	1	2.6	2.2	0.5
Paraquat	1	" MH	1	2.9	2.7	0.0
Paraquat	1	" Varsol		5.2	4.6	0.0
TCA	60			9.9	3.5	0.5
Dalapon	25			10.0	6.8	1.2

The data for July 7, 1964 show that the combination of paraquat at one pound per acre and isocil at one pound per acre resulted in a top-growth control rating of 4.9. However, when this initial paraquat and isocil treatment was followed by a retreatment, when couchgrass regrowth was 4 to 6 inches in height, a final score of 9.5 was obtained. It appears that retreatment with the paraquat and isocil mixture was essential for the herbicide treatment to be lethal.

Plate 5. Plot treated with paraquat (1 lb/ac) and isocil (1 lb/ac) on May 22, 1964, plus chemical retreatment 6 weeks later at similar rates.

Plate 6. Plot treated with paraquat (1 lb/ac)

FenuronTCA, amitrole-T, MH, and varsol in combination with paraquat were relatively ineffective in controlling couchgrass. TCA and dalapon application resulted in effective couchgrass control following treatment, but extensive couchgrass regrowth occurred by September 14, 1964.

B. Evaluation of paraquat and bromacil to control couchgrass

In this experiment the mixtures of paraquat and bromacil were evaluated for couchgrass control. Bromacil was substituted for isocil in the 1965 project because isocil was removed from the commercial market in favour of bromacil. Data are presented in Table 20.

Table 20 - The effect of paraquat and bromacil for couchgrass control

Treatment		Couchgrass Top-growth Control		
Bromacil lb/ac	Paraquat lb/ac	June 12 1965	June 27 1965	July 19 1965
0	0	0.0[b]	0.0	0.0
1/4	0	0.0	0.0	0.0
1/2	0	0.0	0.0	0.0
1	0	0.0	0.5	0.0
0	1/4	3.0	1.0	0.2
1/4	1/4	2.4	0.2	0.0
1/2	1/4	2.0	0.5	0.0
1	1/4	1.5	0.5	0.0
0	1/2	6.5	3.0	0.2
1/4	1/2	6.0	3.0	0.5
1/2	1/2	3.5	2.5	0.0
1	1/2	5.0	3.0	0.0
0	1	9.2	7.4	1.8
1/4	1	6.6	4.5	0.2
1/2	1	9.2	7.9	2.0
1	1	8.5	6.0	1.5

Immediate control of couchgrass top-growth was obtained when mixtures of paraquat and bromacil contained high rates of paraquat. Regrowth of couchgrass occurred regardless of the mixtures of paraquat and bromacil applied. The addition of bromacil to paraquat was relatively ineffective in promoting an additive or synergistic effect between the chemicals. A single herbicide application containing a mixture of paraquat and bromacil was not adequate to control couchgrass.

C. Evaluation of paraquat and rotovation to control couchgrass.

The effectiveness of rotovation and paraquat treatments alone and in different combinations for couchgrass control may be determined from the data in Table 21. Rotovation was more effective in controlling couchgrass than combinations of paraquat and rotovation or paraquat alone. Good control of couchgrass was obtained following 2 initial rotovation treatments, on May 22, 1964 and on July 7, 1964 (Plate 7), but 2 additional rotovations were required on September 14, 1964 and June 16, 1965 to eradicate the couchgrass completely. Alternate treatments with paraquat and rotovation eradicated couchgrass but a total of 3 paraquat and 3 rotovation treatments were required. Similarly, eradication of couchgrass was obtained following 6 consecutive paraquat treatments, each at 2 pounds per acre. Rotovation was the most effective method to control couchgrass requiring only 4 treatments for complete eradication.

Table 21 - The effect of paraquat and rotovation for couchgrass control

Paraquat lb/ac	Number of Treatments		Couchgrass Top-growth Control					
	Paraquat	Rotovation	July 7 1964	Aug. 6 1964	Sept. 14 1964	May 19 1965	June 16 1965	July 30 1965
1/2	6	0	1.2[b]	1.4	3.0	5.1	4.5	5.9
1/2	3	3	1.2	5.8	6.2	8.7	9.2	10.0
1	6	0	3.0	3.4	5.5	7.9	7.4	9.5
1	3	3	3.0	6.2	6.6	9.8	7.4	10.0
2	6	0	3.9	3.5	6.0	8.7	7.7	9.9
2	3	3	3.9	4.0	6.7	9.0	9.5	10.0
0	0	4*[c]	9.8	9.2	8.9	9.0	9.2	10.0
0	0	0	0.0	0.0	0.0	0.0	0.0	0.0

*[c] rotovations were not carried out after the assessments on Aug. 6, 1964 and May 19, 1965.

Plate 7. Check plot (left) and plots rotovated twice (right).

Plate 8. Plot treated with paraquat at one pound per acre in the fall.

D. Fall application of paraquat to control couchgrass

Fall application of paraquat suppressed couchgrass growth in the following spring for approximately one month, after which couchgrass resumed active growth (Table 22).

Table 22 - The effect of fall paraquat application for couchgrass control.

Treatment		Couchgrass Top-growth Control		
Herbicide	Rate lb/ac	May 19 1965	June 5 1965	June 22 1965
Paraquat	1/2	7.9[b]	3.5	1.0
Paraquat	1	9.2	5.2	1.0
Paraquat	2	9.5	6.1	1.8
Check		0.0	0.0	0.0

Application of paraquat at one and 2 pounds per acre resulted in effective couchgrass top-growth control on May 19, 1965. The suppression of couchgrass following fall paraquat application is illustrated in Plate 8. The amount of couchgrass top-growth control increased as the rate of paraquat increased from 1/2 to one pound per acre. Assessments recorded on June 5, 1965 and June 22, 1965 suggested that active couchgrass regrowth had occurred. Thus, the effectiveness of paraquat applied in the fall was limited to one month in the following spring.

CONCLUSIONS

The purpose of this study was to evaluate the performance of paraquat in pasture improvement programs under Manitoba conditions.

Paraquat applied at one pound per acre in the spring was effective in suppressing resident vegetation thus permitting alfalfa establishment. Paraquat was effective in reducing the population of herbaceous perennials but had little effect on the woody perennial plants. 2,4-D; 2,4,5-T applied at 24 ounces per acre prior to parquat treatment had little effect on the population of woody perennials but fair control of the herbaceous perennials was obtained. The results further indicate that 2,4-D:2,4,5-T must be applied at least one year prior to paraquat application and sod-seeding. If 2,4-D:2,4,5-T is applied during the same year as paraquat and alfalfa is sod seeded, then phenoxy residues remain in the soil and will prohibit seed germination of the alfalfa seed.

Fall application of paraquat did not significantly suppress the grasses, woody perennials, or herbaceous perennials in the native pasture and therefore alfalfa could not become established.

During 1964, paraquat successfully controlled wild barley. Control of wild barley increased as the rate of paraquat increased up to 2 pounds per acre. Application of paraquat at various dates during May and June in 1965 failed to control wild barley. However, paraquat application resulted in wild barley suppression for approximately 3 weeks. The suppression of wild barley was long enough to permit the

establishment of alsike clover provided chemical application and seeding were accomplished in May.

Paraquat alone was not adequate to control couchgrass whereas paraquat in combination with other treatments controlled the couchgrass. In 1964, a mixture of paraquat at one pound per acre and isocil at one pound per acre applied on May 22, 1964, followed by a retreatment 6 weeks later, resulted in effective couchgrass control. In 1965, a single application of paraquat at one pound per acre and bromacil at one pound per acre failed to give satisfactory couchgrass control. It appears that retreatment with paraquat at one pound per acre and uracil (isocil and bromacil) at one pound per acre was essential to control couchgrass.

Four rotovation treatments were the most efficient method to eradicate couchgrass. Complete couchgrass eradication was obtained with paraquat at 2 pounds per acre, but 6 separate treatments were required. Also, when treatments consisted of paraquat and rotovation, 6 separate treatments were required.

Fall application of paraquat will suppress couchgrass in the spring for approximately one month. Couchgrass suppression increased as the rate of paraquat increased from 1/2 to one pound per acre.

BIBLIOGRAPHY

1. Alban, E. K., 1960. Chemical weeding of vegetable crops. Annual Proceedings, Ohio Vegetable and Potato Growers Association, 45: 76-84.

2. Alley, H. P., 1962. Quackgrass. Adu. leaflet, University of Wyoming Agricultural Extension Service, Pub. No. 46.

3. Anonymous, 1958. Chemicals for weed control. Manitoba Department of Agriculture and Immigration, Pub. No. 300.

4. Anonymous, 1960. North Scotland College of Agriculture Investigation Research and Field Trials. North Scotland College Agriculture, 76.

5. Anonymous, 1963. West Germany Biologische Bundesanstalt Fur Landund Forstwirtschaft, Braunschweig, J. Ber. Otsch. Pfischdnst, 1961. 10: 316 (Weed Abstracts 13(3):602).

6. Blackmore, L. W., 1958. Overdrilling of pasture and crop. New Zealand Journal of Agriculture, 96: 17-25.

7. Blackmore, L. W., 1958. Overdrilling of pasture and crop. New Zealand Journal of Agriculture, 96: 121-129.

8. Blackmore, L. W., 1960. Chemical pasture establishment on steep hill country. New Zealand Journal of Agriculture, 100: 125-131.

9. Blackmore, L. W., 1962. Bank Spraying A new overdrilling technique. New Zealand Journal of Agriculture, 104: 13-19.

10. Blackmore, L. W., 1964. Chemical establishment and renovation of pasture in Southern Hawkes Bay and Northern Wairaiapa. Proceedings, Seventh British Weed Control Conference, 2: 813-820.

11. Brown, D.A., 1956. Effect of herbicides on couchgrass. Research Report, National Weed Committee (Western Section), 2.

12. Buckholtz, K. P., 1962. How to get the best of quackgrass. Proceedings, North Central Weed Control Conference, 19.

13. Bula, R. J., 1965. Quackgrass progress report. Report, Alaska Experimental Station, (Weed Abstracts 7(11):1961).

14. Carder, A. C., 1956. The effect of A.T.A. and M.H. alone and combined with tillage on couchgrass. Research Report, National Weed Committee (Western Section), 4.

15. Carder, A.C., 1959. Comparative effect of fenuron and monuron when applied to undisturbed couchgrass sod. Research Report, National Weed Committee (Western Section), 2.

Bibliography

16. Carder, A. C., 1960. Spring application of dalapon combined with tillage for the control of couchgrass. Proceedings, North Central Weed Control Conference, 17.

17. Carder, A. C., 1961. Summary of six abstracts of the Research Report, National Weed Committee (Western Section).

18. Carder, A. C., 1963. Effect of paraquat on couchgrass. Research Report, National Weeds Committee (Western Section), 185.

19. Carder, A.C., 1963. Summary of methods of couchgrass control. Research Report, National Weed Committee (Western Section), 181.

20. Carder, A.C., 1963. Tillage plus herbicides for couchgrass eradication. Research Report, National Weed Committee (Western Section), 183.

21. Carder, A.C., 1963. Herbicides for spot eradication of couchgrass. Research Report, National Weed Committee (Western Section), 181.

22. Carder, A.C., 1965. Couchgrass Control. Alberta Department of Agriculture Extension Service, Pub. No. 149.

23. Copeman, G.J.F. and H.W. Roberts, 1960. The development of surface seeding. Journal of British Grassland Society 15: 163-168.

24. Corns, W. G., 1959. Chemical control of couchgrass. Proceedings, Joint meeting of the 16th North Central Weed Control Conference and 10th West Central Weed Control Conference, 34.

25. Corns, W. G., 1960. Effect of amitrole-T on couchgrass. Research Report, North Central Weed Control Conference, 17:83.

26. Cross, M. W. and G.S. Robinson, 1964. Some experiments with short circuiting cultivation. Proceedings, Seventh British Weed Control Conference, 2: 809-812.

27. Elliott, J. G., 1962. Chemical possibilities in grassland. Proceedings, Sixth British Weed Control Conference, 1: 31-36.

28. Elliott, J. G. and G. P. Allen, 1964. The selective control of grasses in permanent pasture. Proceedings, Seventh British Weed Control Conference, 2: 865-878.

29. Evans, E. A., 1964. Sward renovation - some N.A.A.S. (National Agriculture Advisory Service). Proceedings, Seventh British Weed Control Conference, 2: 847-854.

Bibliography

30. Evans, E.A., R.E. Echert, Jr. and B.L. Kay., 1964. A non-tillage method for seeding perennial grasses using paraquat on downy brome-infested rangelands. Proceedings, Seventh British Weed Control Conference, 2: 767-770.

31. Friesen, G., 1963. Control of wild barley on roadsides. Research Report, National Weeds Committee (Western Section), 187.

32. Friesen, G. and L. H. Shebeski, 1960. Economic losses caused by weed competition in Manitoba grain fields. Canadian Journal of Plant Science 40(3): 457-468.

33. Furtick, W. R., 1964. The use of herbicides for renovation and improvement of grasslands. Proceedings, Seventh British Weed Control Conference 2: 783-791.

34. Gautier, J. L., 1963. Substituted Uracils in industrial weed control. Conf. Com. Franc Nauv. Herbes (Columa):2 (Weed Abstracts 13(1):167).

35. Gleeson, T., 1964. Field factors influencing pasture reseeding following the use of herbicides. Proceedings, Seventh British Weed Control Conference 2: 855-864.

36. Helgason, E. A., 1965. Quackgrass. Research Report, North Central Weed Control Conference 13: 37-45.

37. Halm, L. G. and G. Frank, 1960. The eradication of quackgrass adjacent to young cherry trees. Research Report, North Central Weed Control Conference 17: 103.

38. Hughes, R. G., 1964. Herbicides for couch control I.C.A.M.J. 12(1) 27-29. (Weed Abstract 13(3): 740).

39. Jeater, R.S.L. and H. C. McIlvenny, 1960. The control of perennial grasses with dipyridyl herbicides alone and in mixtures. Proceedings, Fifth British Weed Control Conference 1: 311-320.

40. Jones, L., 1962. Herbicides to aid pasture renovation. Journal British Grasslands 17: 85-86.

41. Kaspirova, T. A., 1960. The use of herbicides to control couch-grass in orchards S.Kh. S.W. Zop. Zony 6: 81-33. (Weed Abstracts 10(2): 1053).

42. Kay, B. L., 1964. Paraquat - An aid to the seeding and management of range lands in the mediterranean climate of California. Proceedings, Seventh British Weed Control Conference 2: 771-774.

Bibliography

43. Matthews, L. J., 1964. Review of pasture weed control in New Zealand. Proceedings, Seventh British Weed Control Conference 2:803-808.

44. McCurdy, E. V., 1964. Control of wild barley growing on a saline soil. Research Report, National Weeds Committee (Western Section), 217.

45. Norway, N. J., 1960. Results of the associated Scandinavian plan for control of Agropyron repens. Nord. Jordbrforskn. Suppl. 1:132-138. (Weed Abstracts 10(5):903).

46. Peters, R. A., 1960. Observation on the use of herbicides for renovation of non-tillable pasture. Proceedings, North East Weed Control Conference 14: 314-319.

47. Pisareua, M. G., 1961. Herbicides in horticulture Sadovodstvo 6: 25-26. (Weed Abstracts 11(4): 1033).

48. Procter, J. M., 1960. Rotary cultivation for the control of couch. Proceedings, Fifth British Weed Control Conference 1:265-269.

49. Roberts, H. W., 1960. The delayed application of nitrogen for the establishment of surface seeded swards. Journal of British Grassland Society 15: 287-290.

50. Ross, M. A. and P. F. Cocks, 1964. The use of bipyridyls as an aid to pasture renovation in South Australia. Proceedings, Seventh British Weed Control Conference 2: 821-824.

51. Selleck, G. W., 1960. Herbicides for leafy spurge control. Proceedings, North Central Weed Control Conference 17:91.

52. Selleck, G. W., 1960. Herbicides for toadflax control. Research Report, National Weed Committee (Western Section) 14.

53. Sprague, M.A., 1952. The substitution of chemicals for tillage in pasture renovation. Agronomy Journal 44: 405-409.

54. Taylor, T.H., J. M. England, R. E. Powell, J. F. Freeman, C. K. Kline, and W. C. Templeton Jr., 1964. Establishment of legumes in old Poa pratensis L. sod by use of paraquat and strip-tillage for seed bed preparation. Proceedings, Seventh British Weed Control Conference 2:792-802.

55. Vanden Born, W. H., 1963. Comparison of several herbicides for the control of foxtail barley. Research Report, National Weed Committee (Western Section), 187.

Bibliography

56. Verlaat, J. G., 1959. Chemical weed control in the autumn. Groenten en Fruit 15(7):195. (Weed Abstracts 10(9):1546).

57. Young, J. F., 1964. The use of paraquat in hill land surface seeding. Proceedings, Seventh British Weed Control Conference 2: 825-828.

- APPENDICES -

Appendix 1. Meteorological data: temperature and precipitation summary for Portage la Prairie, April to September 1964 and 1965.

Temperature Summary

Month	Average Maximum		Average Minimum		Mean Daily		Deviation from Normal	
	1964 °F	1965 °F	1964 °F	1965 °F	1964 °F	1965 °F	1964 °F	1965 °F
April	31.3	46.3	30.9	30.2	41.1	38.3	+3.2	+0.6
May	61.3	62.3	42.5	38.5	54.9	50.4	+3.9	-0.6
June	71.3	74.1	48.3	51.2	59.8	62.4	-1.3	+1.3
July	79.7	76.7	57.4	52.5	68.6	64.0	+0.7	-3.9
August	71.7	76.3	50.5	31.0	61.1	63.7	-4.6	-2.0
September	63.5	55.7	39.8	36.7	51.7	46.3	-2.1	-7.3

Precipitation Summary

Month	Total Monthly Precipitation		Deviation from Normal	
	1964 inches	1965 inches	1964 inches	1965 inches
April	1.07	2.09	-0.04	+0.98
May	1.37	4.05	-1.17	+1.51
June	5.10	1.14	+1.23	-2.73
July	3.08	3.77	+0.10	+0.79
August	4.56	1.51	+1.63	-1.42
September	1.37	3.61	-1.10	+1.14

Appendix 2. Percent plant cover in spring pasture project 1964-1965.

Treatment Herbicide Rate(lb/ac)	Percent Plant Cover					
	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Total Cover						
Paraquat 1/4	66.8	47.6	76.3	56.5	77.2	84.5
Paraquat 1/2	66.5	44.7	79.5	58.2	76.4	85.8
Paraquat 1	68.5	25.8	67.4	62.9	79.3	87.7
Check	63.0	73.6	86.9	46.1	83.0	80.5
Grasses						
Paraquat 1/4	51.4	37.2	46.0	48.2	50.5	51.0
Paraquat 1/2	47.7	28.6	37.2	52.5	47.6	46.3
Parawuat 1	44.2	18.0	29.5	47.8	35.9	31.2
Check	48.4	47.9	48.8	42.6	52.4	56.6
Herbaceous Perennials						
Paraquat 1/4	13.7	7.7	20.2	1.5	11.3	14.0
Paraquat 1/2	16.2	13.2	19.7	1.7	13.4	8.0
Paraquat 1	21.9	3.2	13.2	2.0	4.9	6.0
Check	12.9	23.0	29.4	0.4	12.0	16.4
Woody Perennials						
Paraquat 1/4	1.7	2.7	7.3	5.3	9.5	3.4
Paraquat 1/2	2.6	2.9	11.9	2.9	10.8	7.7
Paraquat 1	2.4	4.6	11.5	5.6	17.9	4.9
Check	1.7	2.7	8.4	3.1	18.6	7.5
Alfalfa						
Paraquat 1/4	-	-	2.8	1.5	5.9	16.1
Paraquat 1/2	-	-	5.7	1.1	4.6	23.8
Paraquat 1	-	-	13.2	7.5	20.6	45.6
Check	-		0.3	-	-	-

Appendix 3. Analysis of total plant cover at varying dates for spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	10.42	0.50
Treatments	3	9.03	0.44
Error	9	20.65	
July 14, 1964			
Replicates	3	6.07	0.19
Treatments	3	564.22	18.21**
Error	9	30.98	
August 12, 1964			
Replicates	3	32.76	2.16
Treatments	3	125.50	8.27**
Error	9	15.17	
May 19, 1965			
Replicates	3	13.18	1.42
Treatments	3	67.75	7.31**
Error	9	9.27	
June 22, 1965			
Replicates	3	37.27	4.98*
Treatments	3	3.18	0.42
Error	9	7.49	
August 16, 1965			
Replicates	3	32.31	0.90
Treatments	3	31.17	0.87
Error	9	35.84	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Appendix 4. Analysis of grass cover at varying dates for spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	124.00	7.57*
Treatments	3	11.63	0.71
Error	9	16.39	
July 14, 1964			
Replicates	3	126.59	2.35
Treatments	3	275.20	5.12*
Error	9	53.75	
August 12, 1964			
Replicates	3	302.97	4.18*
Treatments	3	110.43	1.52
Error	9	72.48	
May 19, 1965			
Replicates	3	28.81	2.55
Treatments	3	21.89	1.94
Error	9	11.30	
June 22, 1965			
Replicates	3	147.73	4.97*
Treatments	3	76.88	2.59
Error	9	29.73	
August 16, 1965			
Replicates	3	144.07	1.45
Treatments	3	48.88	0.49
Error	9	99.29	

* Significant at the 5% level of probability.

Appendix 5. Analysis of woody perennial cover at varying dates for spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	27.35	1.52
Treatments	3	4.34	0.24
Error	9	18.04	
July 14, 1964			
Replicates	3	63.55	2.30
Treatments	3	6.60	0.23
Error	9	27.57	
August 12, 1964			
Replicates	3	303.66	6.08*
Treatments	3	28.42	0.57
Error	9	49.97	
May 19, 1965			
Replicates	3	220.95	27.11**
Treatments	3	8.45	1.04
Error	9	8.15	
June 22, 1965			
Replicates	3	362.24	4.71*
Treatments	3	13.33	0.17
Error	9	76.95	
August 16, 1965			
Replicates	3	167.36	3.11
Treatments	3	24.40	0.45
Error	9	53.85	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Appendix 6. Analysis of herbaceous perennial cover at varying dates for spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	211.00	4.61*
Treatments	3	45.20	0.98
Error	9	45.73	
July 14, 1964			
Replicates	3	277.39	7.55**
Treatments	3	215.63	5.87*
Error	9	36.72	
August 12, 1964			
Replicates	3	557.42	12.75**
Treatments	3	141.66	3.24
Error	9	43.72	
May 19, 1965			
Replicates	3	78.91	9.43**
Treatments	3	12.94	1.53
Error	9	8.45	
June 22, 1965			
Replicates	3	391.61	9.43**
Treatments	3	46.72	1.12
Error	9	41.53	
August 16, 1965			
Replicates	3	511.05	7.52**
Treatments	3	90.93	1.34
Error	9	68.00	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Appendix 7. Analysis of alfalfa cover at varying dates for spring pasture project 1964-1965.

Source of Variance	D.F.	M.S.	F
August 12, 1964			
Replicates	3	12.32	0.18
Treatments	3	271.60	3.89*
Error	9	69.84	
May 19, 1965			
Replicates	3	34.69	0.70
Treatments	3	118.42	2.38
Error	9	49.71	
June 22, 1965			
Replicates	3	67.86	0.43
Treatments	3	425.86	2.72
Error	9	156.30	
August 16, 1965			
Replicates	3	81.55	0.18
Treatments	3	1,301.13	2.90
Error	9	443.66	

* Significant at the 5% level of probability.

Appendix 8. Percent plant cover in the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Treatment Herbicide Rate(lb/ac)	Percent Plant Cover					
	June 15 1964	July 14 1964	Aug. 12 1964	May 19 1965	June 22 1965	Aug. 16 1965
Total Cover						
Paraquat 1/4	78.4	30.4	70.9	56.8	56.9	76.6
Paraquat 1/2	79.4	21.2	72.0	52.9	44.2	70.2
Paraquat 1	77.7	14.2	69.5	56.7	42.9	86.4
Check	79.6	63.8	83.8	49.5	74.0	76.7
Grasses						
Paraquat 1/4	54.6	24.1	52.1	54.7	43.3	54.8
Paraquat 1/2	59.3	13.3	53.4	50.2	24.2	44.4
Paraquat 1	53.3	8.7	43.7	54.2	24.5	44.5
Check	53.2	59.8	71.9	46.9	57.6	62.6
Woody Perennials						
Paraquat 1/4	1.5	1.8	10.6	0.6	8.7	12.1
Paraquat 1/2	1.5	1.8	9.0	1.9	11.3	12.0
Paraquat 1	1.2	3.3	13.6	1.7	10.4	16.7
Check	3.2	2.6	5.3	2.1	13.3	11.4
Herbaceous Perennials						
Paraquat 1/4	22.3	4.5	8.0	1.5	4.9	8.1
Paraquat 1/2	18.6	6.1	8.7	0.8	8.1	6.2
Paraquat 1	23.2	2.2	9.5	0.6	8.0	11.1
Check	23.2	1.4	6.6	0.5	3.1	2.7
Alfalfa						
Paraquat 1/4	-	-	0.2	-	-	1.6
Paraquat 1/2	-	-	0.9	-	0.6	7.6
Paraquat 1	-	-	2.7	0.2	-	14.1
Check	-	-	-	-	-	-

Appendix 9. Analysis of total plant cover at varying dates for the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	97.05	17.26**
Treatments	3	1.13	0.20
Error	9	5.62	
July 14, 1964			
Replicates	3	13.63	0.44
Treatments	3	734.09	23.89**
Error	9	30.72	
August 12, 1964			
Replicates	3	6.50	0.74
Treatments	3	83.70	9.58**
Error	9	8.73	
May 19, 1965			
Replicates	3	46.57	2.41
Treatments	3	16.14	0.83
Error	9	19.30	
June 22, 1965			
Replicates	3	14.78	0.81
Treatments	3	281.38	15.51**
Error	9	18.14	
August 16, 1965			
Replicates	3	45.83	0.69
Treatments	3	47.01	0.70
Error	9	66.26	

** Significant at the 1% level of probability.

Appendix 10. Analysis of grass cover at varying dates for the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	191.24	12.74**
Treatments	3	10.64	0.70
Error	9	15.01	
July 14, 1964			
Replicates	3	7.38	1.07
Treatments	3	227.27	33.03**
Error	9	6.88	
August 12, 1964			
Replicates	3	75.93	2.77
Treatments	3	200.80	7.33**
Error	9	27.37	
May 19, 1965			
Replicates	3	47.25	3.46
Treatments	3	18.21	1.33
Error	9	13.63	
June 22, 1965			
Replicates	3	37.00	3.95
Treatments	3	382.08	40.86**
Error	9	9.35	
August 16, 1965			
Replicates	3	120.07	3.96*
Treatments	3	107.46	3.54
Error	9	30.31	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Appendix 11. Analysis of woody perennials cover at varying dates for the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	18.38	1.46
Treatments	3	18.76	1.49
Error	9	12.56	
July 14, 1964			
Replicates	3	1.00	0.02
Treatments	3	3.73	0.08
Error	9	42.84	
August 12, 1964			
Replicates	3	7.18	0.08
Treatments	3	45.74	0.55
Error	9	81.79	
May 19, 1965			
Replicates	3	7.91	0.34
Treatments	3	11.64	0.50
Error	9	23.07	
June 22, 1965			
Replicates	3	69.63	1.96
Treatments	3	13.98	0.39
Error	9	35.42	
August 16, 1965			
Replicates	3	27.77	0.47
Treatments	3	10.11	0.17
Error	9	58.67	

Appendix 12. Analysis of herbaceous perennial cover at varying dates for the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
June 15, 1964			
Replicates	3	75.95	5.08*
Treatments	3	8.37	0.55
Error	9	14.95	
July 14, 1964			
Replicates	3	192.46	3.40
Treatments	3	16.09	0.28
Error	9	56.52	
August 12, 1964			
Replicates	3	337.83	4.06*
Treatments	3	4.73	0.05
Error	9	83.10	
May 19, 1965			
Replicates	3	2.02	0.10
Treatments	3	7.72	0.39
Error	9	19.34	
June 22, 1965			
Replicates	3	149.99	3.06
Treatments	3	37.64	0.76
Error	9	48.97	
August 16, 1965			
Replicates	3	176.38	3.63
Treatments	3	73.40	1.51
Error	9	48.54	

* Significant at the 5% level of probability.

Appendix 13. Analysis of alfalfa cover at varying dates for the 2,4-D:2,4,5-T pretreated spring pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
August 16, 1965			
Replicates	3	60.23	2.95
Treatments	3	354.23	17.38**
Error	9	20.38	

** Significant at the 1% level of probability.

Appendix 14. Percent plant cover in the fall pasture project 1964-1965.

Treatment Herbicide Rate(lb/ac	Percent Plant Cover Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Total Cover				
Paraquat 1/2	72.7	51.4	62.1	68.9
Paraquat 1	69.7	51.1	70.3	70.7
Paraquat 1-1/2	74.0	48.9	67.8	75.2
Paraquat 1/4 + Diquat 1/4	72.8	53.0	62.5	67.8
Paraquat 1/2 + Diquat 1/2	71.7	56.0	67.0	69.0
Paraquat 3/4 + Diquat 3/4	70.0	48.7	70.8	72.9
Dalapon 4	69.8	35.4	71.5	78.4
Check	70.5	54.2	68.8	73.8
Grasses				
Paraquat 1/2	54.4	33.0	27.7	28.6
Paraquat 1	53.3	35.4	28.4	28.4
Paraquat 1-1/2	50.0	28.3	24.4	29.5
Paraquat 1/4 + Diquat 1/4	50.9	34.8	29.7	30.8
Paraquat 1/2 + Diquat 1/2	52.8	39.5	29.1	31.0
Paraquat 3/4 + Diquat 3/4	48.5	31.3	29.5	26.6
Dalapon 4	48.8	19.0	18.4	23.1
Check	52.1	34.2	29.0	27.0

Appendix 14 (cont.)	Sept. 12 1964	June 9 1965	July 15 1965	Aug. 18 1965
Woody Perennials				
Paraquat 1/2	3.4	2.1	7.3	8.0
Paraquat 1	1.3	3.3	8.6	9.1
Paraquat 1-1/2	5.0	5.1	10.8	10.9
Paraquat 1/4 + Diquat 1/4	1.4	1.3	3.2	2.7
Paraquat 1/2 + Diquat 1/2	1.0	0.9	5.6	6.2
Paraquat 3/4 + Diquat 3/4	4.1	3.7	8.8	9.8
Dalapon 4	3.1	5.8	9.0	10.1
Check	4.4	3.7	9.1	7.9
Herbaceous Perennials				
Paraquat 1/2	14.9	16.3	25.5	24.9
Paraquat 1	15.1	12.4	29.5	24.8
Paraquat 1-1/2	19.0	15.5	30.1	29.9
Paraquat 1/4 + Diquat 1/4	20.5	16.9	26.9	28.8
Paraquat 1/2 + Diquat 1/2	17.9	15.6	30.9	28.7
Paraquat 3/4 + Diquat 3/4	17.4	13.7	27.1	24.0
Dalapon 4	17.9	10.6	41.7	39.2
Check	14.0	16.3	28.6	32.9
Alfalfa				
Paraquat 1/2	-	-	1.6	7.4
Paraquat 1	-	-	3.8	8.4
Paraquat 1-1/2	-	-	2.5	4.9
Paraquat 1/4 + Diquat 1/4	-	-	2.7	5.5
Paraquat 1/2 + Diquat 1/2	-	-	1.4	3.1
Paraquat 3/4 + Diquat 3/4	-	-	5.4	12.5
Dalapon 4	-	-	2.4	6.0
Check	-	-	2.1	6.0

Appendix 15. Analysis of total plant cover at varying dates for the fall pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
September 12, 1964			
Replicates	3	13.71	0.43
Treatments	7	16.90	0.52
Error	21	32.24	
June 9, 1965			
Replicates	3	8.99	0.52
Treatments	7	55.32	3.21*
Error	21	17.21	
July 15, 1965			
Replicates	3	34.57	1.50
Treatments	7	36.75	1.59
Error	21	23.01	
August 18, 1965			
Replicates	3	11.32	0.72
Treatments	7	24.67	1.57
Error	21	15.67	

* Significant at the 5% level of probability.

Appendix 16. Analysis of grass cover at varying dates for the fall pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
September 12, 1964			
Replicates	3	84.68	8.46**
Treatments	7	5.84	0.58
Error	21	10.01	
June 9, 1965			
Replicates	3	21.32	1.22
Treatments	7	62.4	3.56*
Error	21	17.53	
July 15, 1965			
Replicates	3	41.76	4.12*
Treatments	7	26.71	2.63*
Error	21	10.14	
August 18, 1965			
Replicates	3	14.04	0.76
Treatments	7	11.12	0.6
Error	21	18.46	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Appendix 17. Analysis of woody perennial cover at varying dates for the fall pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
September 12, 1964			
Replicates	3	15.07	0.34
Treatments	7	31.14	0.69
Error	21	44.98	
June 9, 1965			
Replicates	3	84.14	2.76
Treatments	7	40.06	1.31
Error	21	30.51	
July 15, 1965			
Replicates	3	242.89	3.25*
Treatments	7	21.89	0.29
Error	21	74.79	
August 18, 1965			
Replicates	3	260.96	3.91*
Treatments	7	33.98	0.51
Error	21	66.74	

* Significant at the 5% level of probability.

Appendix 18. Analysis of herbaceous perennial cover at varying dates for the fall pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
September 12, 1964			
Replicates	3	59.37	1.98
Treatments	7	13.09	0.44
Error	21	29.98	
June 9, 1965			
Replicates	3	31.94	1.90
Treatments	7	13.72	0.82
Error	21	16.77	
July 15, 1965			
Replicates	3	6.15	0.23
Treatments	7	40.08	1.52
Error	21	26.35	
August 18, 1965			
Replicates	3	9.46	0.47
Treatments	7	43.39	2.18
Error	21	20.11	

Appendix 19. Analysis of alfalfa cover at varying dates for the fall pasture project 1964-1965.

Source of variance	D.F.	M.S.	F
July 15, 1965			
Replicates	3	20.50	1.15
Treatments	7	12.96	0.73
Error	21	17.87	
August 18, 1965			
Replicates	3	9.74	0.47
Treatments	7	35.97	1.72
Error	21	20.98	

Appendix 20. Analysis of alsike clover cover following paraquat treatment on wild barley.

Source of variance	D.F.	M.S.	F
Replicates	1	2.06	
Dates	4	629.58	30.87**
Error (a)	4	20.39	
Sub-total	9		
Treatments	1	18.11	1.01
Dates X Treatments	4	82.37	4.63
Error (b)	5	17.79	
Total	19		

** Significant at the 1% level of probability.