

A STUDY OF THE CONTROL OF CLIMBING  
MILKWEED (GONOLOBUS LAEVIS) WITH CHEMICALS

by

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## INTRODUCTION

A weed may be defined as an undesirable plant or a "plant out of place". Weeds compete for a place in the soil by occupying space. They also compete for soil nutrients and thereby reduce not only the yield, but also the quality of farm crops. Both woody and herbaceous plants may be weeds, and they can cause losses in many ways. Hildebrand (20) reported that most virus diseases of plants are spread by insects and in every known case weeds serve as hosts for the insect vector and may also harbor the virus pathogen. Many fungous and bacterial diseases of plants overwinter on, or are harbored by, weeds (e.g. downy mildew of lettuce winters on wild sunflower and thistles).

Many weed seeds persist for long periods of time in the soil when buried in the plowing operation. Darlington (16) reported that in 1879, Dr. W. J. Beal at the Michigan Agricultural Experiment Station, buried 1000 freshly gathered seeds each of 20 different plants in 18 inches of soil. Many of these seeds were viable after a period of 60 years. Goss (14) revealed that seed was buried by the United States Department of Agriculture in 1902. These seeds consisted of 107 species of cultivated and wild plants. After 20 years, 51 of these 107 species showed fairly high germination.

Each cultivation usually starts off a new crop of weeds. While there are numerous species (annual, biennial, or perennial in habit), only a relatively few are of serious economic importance for any one crop. Annuals, in passing through their complete cycle

back to seed in one season, are vulnerable to herbicides, especially when small. For the perennials, the situation is different because the herbicide must be capable of reaching the underground parts if it is to be successful. Gates (13) reported climbing milkweed, Gonolobus laevis<sup>1</sup>, to be a perennial reproducing from a succulent taproot system, from lateral roots, and from seeds. Further observation showed that where field bindweed, Convolvulus arvensis, and climbing milkweed infested the same area, climbing milkweed persisted after the bindweed root system yielded to starvation when properly cultivated as recommended for eradication.

Frazier (12) found the root system of well established climbing milkweed plants consisted of the original root which he called the primary vertical and one to many permanent laterals which continued to grow horizontally. Secondary vertical roots were found growing downward from these permanent laterals after a short horizontal growth. Hitchcock and Clothier (21) referred to this weed as Enslonia alluda (Nutt.) in their early studies and found roots extending to a depth of 7 feet at Manhattan, Kansas. These plants were of unknown age. Frazier (12) found that climbing milkweed plants sent primary vertical roots to a depth of 42 inches and had produced four permanent lateral roots of the first order 25 weeks after seedling emergence.

Gates (13) stated that climbing milkweed was found in the

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<sup>1</sup>Throughout the remainder of this thesis Gonolobus laevis shall be referred to by its common name, climbing milkweed.

eastern two-thirds of Kansas and most extensively in central Kansas counties. After an intensive weed survey of central and eastern counties, Yost (3<sup>4</sup>) has determined the climbing milkweed infestations to be in the area shown in Fig. 1. The persistence and spread of this weed due to its extensive root system, relative tolerance to any method of eradication, and the fact that the seed is readily disseminated by wind and water has resulted in an infestation of over 200,000 acres<sup>2</sup> in Kansas counties. This ever-increasing crop menace and the fact that no effective method of control has been found induced the writer to investigate the possibility of controlling this weed with selective herbicides.

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<sup>2</sup>Based on county weed survey conducted by the State Board of Agriculture (1948).



## NATURE AND ACTION OF SELECTIVE HERBICIDES

The term "selective herbicide", in its widest sense, applies to any chemical that will kill weeds in a growing crop without injuring that crop beyond the point of recovery. This selective or differential action of sprays is due to differences in the structure of the plant; the nature of the surfaces of the plants; or may be due to true physiological selectivity.

As stated by Hildebrand (20) the principle of selective weed killing has been known for over a half century. Concentrated iron sulphate in solution was used with some success for treating weeds in cereals for many years in both Europe and America.

It was in 1944 that strange curling effects were noted on bindweed which had been sprayed with one of the so-called "hormone" chemicals, 2,4-Dichlorophenoxyacetic acid.<sup>3</sup> Some of these plants died later (24).

Robbins, Crafts, and Raynor (26) stated that an aqueous spray applied to a field of wheat containing mustard, behaves differently in accordance with their structural differences. Smooth waxy leaves of wheat are not appreciably wetted by drops of the spray solution, and the drops have a tendency to remain spherical, with only a small point of contact with the leaves. Because of the erect position of the leaves on the wheat plant most of the drops roll off. The leaves of mustard are readily wettable and the spray drops have a tendency to spread out and coalesce thus forming

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<sup>3</sup>2,4-Dichlorophenoxyacetic acid will be referred to hereafter as 2,4-D.

a continuous film of solution over the entire leaf surface.

Since the introduction of 2,4-D, several mechanical factors have been considered to increase its efficiency. Special types of spray nozzles, and low air pressure when spraying have made it possible to spray vast acreages with a limited amount of spray solution. The extremely fine particles of spray solution ejected from the spray apparatus under these conditions adhere to the plant surfaces to form a thin film. The addition of emulsifying agents to the spray solutions to reduce surface tension have also prevented the formation of large spray droplets and the loss of these materials from the leaves of the plants.

Crafts (4) stated that the growth regulating compounds are absorbed through the leaves and translocated from foliage to roots apparently in the same way as naturally occurring plant hormones.

The first noticeable effects of 2,4-D as stated by Harvey and Robbins (18) are in the stems and leaves, which twist and bend, the stems sometimes forming loops and coils. In some plants, the stems and leaves dry until the tops are completely dead; in others, the stems remain green for several weeks, but may swell, develop cracks, and form callus tissue. Sometimes thick pads of tissue develop along stems and at the joints. Often, numerous watery, translucent buds appear at the crown but do not grow into new shoots. Before dropping, leaves of some woody plants change their color to red or yellow. Several weeks after treatment, seriously affected plants may show spongy, enlarged roots. The outer portion of the root may slough off and leave wet, stringy

cores that will later dry or rot.

Weaver, et al. (32) state that when 2,4-D is brought into contact with the plants, it presumably enters by penetration of the cuticle, epidermal layer, and underlying cells. Young plants of nasturtium having stomata only on the underside of the leaf, were sprayed with a 0.1 percent solution of ammonium salt of 2,4-D, and the results indicated that regardless of the leaf surface sprayed, the degree of inhibition was independent of the stomata. Other tests on red kidney bean in which 2,4-D was applied to scratched and to uninjured portions of the leaves revealed that rupturing the leaf tissue did not aid entry of the agent into the plant. Applications of 2,4-D on the soybean plant indicated that the maximum amount of the compound entered the plant within six hours after the treatment.

The Kansas Agricultural Experiment Station (35) reported the testing of 2,4-D in more than 500 experimental plots at Canton, Hays, and Manhattan, Kansas, during the summer of 1945. Extensive tests on field bindweed (Convolvulus arvensis), hoary cress (Leptidium draba), Russian knapweed (Centaurea repens), and Canada thistle (Cirsium arvense), resulted in killing the tops and quite often the roots to a depth of 6 to 18 inches. Some regrowth was noted; however, this indicated satisfactory control with repeated treatments.

Crafts (4) reported that many workers have shown that cereal and grass crops exhibit considerable tolerance to 2,4-D; whereas most broad-leaved plants, including many weed species are highly

susceptible. As shown by Hanson (16), a number of common weeds in lawns were killed by spraying with 2,4-D with no noticeable damage to the grasses.

Viehmeyer (31) reported the treatment of buffalo grass, (Buchloe dactyloides), and the wheat grasses, (Agropyron spp.) with 2,4-D at a concentration of 3000 ppm without loss of stand. On the other hand, sand love grass, (Eragrostis trichodes), was killed at concentrations of 2000 ppm. Helgeson (19) stated the co-operative reports from several experiment stations indicate that applications of 2,4-D to foliage of corn in the early stages of growth may reduce the yield. Bakke and Sylvester (1) have stated that corn may be damaged if sprayed before the ears have reached the milk stage. In line with these observations Rossman and Staniforth (27) found serious reductions in seed yields and seedling vigor of four inbred lines of corn when sprayed with 2,4-D at the six to eight leaf stage and during the period of pollination. On the other hand, a single cross hybrid was relatively unaffected by aqueous solutions of the sodium salt of 2,4-D, but the addition of a detergent, Drest, to the solutions produced vegetative response, yield reductions, and a response in the seed produced on the treated plants.

Taylor (30) reported a stimulation on the growth of corn by pretreating the soil with 2,4-D. Viehmeyer (31) found that dandelion, (Taraxacum vulgare), failed to germinate on soil previously treated with 2,4-D while untreated soil a few feet away produced thousands of seedlings. The Kansas Agricultural Experiment Station

(35) reported that the effect of 2,4-D upon the soil seemed to be rather severe but temporary. In most cases the toxic effects disappeared in 4 to 8 weeks.

Jones (23) showed by two laboratory experiments that rates of 2,4-D as high as 25 pounds per acre had no detrimental influence upon nitrate production in a soil to which no nitrogen had been added; while 15 pounds of 2,4-D per acre was effective in inhibiting temporarily the formation of nitrates when the nitrogen was added to the soil in the form of urea or sodium nitrate.

Marth et al. (25) reported that seed stalks and seed heads developed on 2,4-D treated timothy, and that the germination of seed on plots treated in various ways was unaffected. Hammer et al. (15) soaked seeds of rape, ryegrass, field pea, brome grass, meadow fescue, creeping bent grass, orchard grass, hairy vetch, and alsike clover with 2,4-D at concentrations of 10 and 100 ppm. The germination of these seeds was greatly inhibited, with only a few of the grasses appearing in the 10 ppm. treatment.

## EXPERIMENTAL MATERIALS AND METHODS

Each year the problem of the control of climbing milkweed arises throughout the eastern portion of Kansas. This weed pest causes a serious loss to Kansas crops due to its competition for soil nutrients and the difficulty of harvesting a crop where it is prevalent. The infestations in row crops are most important as such crops are entangled and broken at the crown due to the increased weight and vining habit of this weed. Therefore, it was decided to try to find a program of control which would be both practical and effective.

After considering previous methods of weed control in farm crops, and the fact that treatments would be necessary within the row to control climbing milkweed, a spray program was outlined.

It should be noted that a given rate of application of a chemical does not give the same degree of control of weeds in every case. Even on the same weed, a treatment that gives complete control under one set of conditions will be a total failure under another set. It is therefore necessary in gauging dosages to recognize and evaluate the several factors which may influence the percentage of the weed population that will be killed. These factors are (1) the kinds of weeds present, (2) their size and age, (3) their growth history in terms of environmental conditions, (4) weather conditions at and immediately after spraying, and (5) the relation between concentration and volume of spray applied to a given area.

## Chemicals

Several chemicals were employed to determine the most feasible chemical for satisfactorily controlling climbing milkweed. Borax and sodium chlorate were used as an index for comparing the results of 2,4-D compounds.

The most common forms of 2,4-D are the acid (2,4-dichlorophenoxyacetic acid) and the salts and esters of this acid. The term 2,4-D applies both to the parent acid and its derivatives. The acid itself is a crystalline material almost insoluble in water. It is usually formulated so that it will form either a solution or a suspension when diluted with water. The salts of the parent acid, such as sodium or ammonium salt, are dry powders readily dissolved in water, and easily prepared. The esters used in the commercial 2,4-D products dissolve more slowly in water. They will, however, dissolve easily in oil, and for this reason, the esters are usually sold in an oil preparation which mixes readily with water to form an emulsion. 2,4,5-Trichlorophenoxyacetic acid<sup>4</sup> is a compound closely related to the ester formulations of 2,4-D. The chemicals and their components are given in Table 3.

## Equipment and Application

In conducting the germination tests on climbing milkweed seed, the seed was placed on heavy blotter (germinating) paper

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<sup>4</sup>This compound shall be referred to hereafter as 2,4,5-T.

or imbedded in a layer of fine sand and placed in a Minnesota seed germinator.

Since spray applications were made in both the laboratory and the field, two different types of apparatus were employed to enable accurate measurement of liquids and insure sufficient coverage of the foliage.

The apparatus used in the laboratory involved a hand operated bulb atomizer attached to a calibrated glass bottle. The vacuum created by squeezing the bulb was sufficient to dispense the liquid on the plants in the form of a fine mist. A heavy cardboard shield was placed around each series of plants treated during the spraying operation to prevent any drift of material.

Field applications were made with a three gallon hand operated Hudson knapsack sprayer at a pressure varying from 30 to 40 pounds per square inch. The amount of spray material was measured for each plot before each spray application and one plot only was sprayed at a time. The sprayer was washed thoroughly with water before using a different chemical with the most potent chemical being the last one used.

In order to assure sufficient coverage of the foliage and the least drift of spray materials, all applications were made when wind velocities were low. High soil moisture and atmospheric temperatures of 70° F. or above were prevalent when the chemicals were applied.

### Seed Tests and Results

According to Gates (13), climbing milkweed has infested new lands from seed which may be disseminated readily by wind, water, or mechanical means. These seeds are approximately 1 centimeter in length, flat, light brown, winged and possess a parachute of hairs.

A number of seed pods were collected in both cultivated and noncultivated fields in Riley County, Kansas. Each seed pod examined contained from 70 to 165 seeds. This seed, in turn, was germinated under various conditions in the laboratory to determine the conditions most suitable for such germination in the field. A summary of the results and the percent germination are shown in Table 1.

Another series of seed was soaked in solutions of 2,4-D and 2,4,5-T at varying concentrations for 24 and 48 hours. This seed was then removed from the chemical solutions, washed in running water for 30 minutes and placed in the germinator at a constant temperature of 30°C. for 14 days. A summary of the chemical treatment and the percent germination are shown in Table 2.

Table 1. Summary of seed treatment and percent germination of climbing milkweed (*Gonolobus laevis*) seed.

Test no.:	Pre-germination: seed treatment:	Temperature:	Germinating media:	Percent germination	
				6 days	14 days
1	None	20°-30°C <sup>1</sup>	Paper <sup>2</sup>	60.0	100.0
2	Warm water-3hrs (soaked)	20°-30°C	Paper	63.0	96.0
3	Prechilled <sup>3</sup>	20°-30°C	Paper	80.0	80.0
4	None	20°-30°C	Sand	0.0	85.0
5	Warm water-3hrs (soaked)	20°-30°C	Sand	0.0	70.0
6	None	20°C	Paper	0.0	0.0
7	Warm water-3hrs (soaked)	20°C	Paper	0.0	0.0
8	None	20°C	Sand	0.0	0.0
9	Warm water-3hrs (soaked)	20°C	Sand	0.0	0.0
10	None	30°C	Paper	86.6	86.6
11	Warm water-3hrs (soaked)	30°C	Paper	100.0	100.0

<sup>1</sup>Seed was subjected to temperature of 30°C. for 8 hours and to a temperature of 20° C. for 16 hours during a 24 hour period.

<sup>2</sup>Heavy blotter paper used for germination.

<sup>3</sup>Prechilled 5 days at 40° F.

Table 2. Summary and results of chemical seed treatment and percent germination of climbing milkweed (*Gonolobus laevis*), seed.<sup>1</sup>

Test No.	Chemical treatment		Percent germination			
	Pre-Germination : seed treatment :	Concentration : ppm	6 days		14 days	
			24hrs	48hrs	24hrs	48hrs
1	2,4-D(Sodium salt)	250	10.0	5.0	30.0	14.3
2	2,4,5-T	250	0.0	0.0	0.0	0.0
3	2,4-D(Sodium salt)	500	0.0	0.0	5.0	5.0
4	2,4,5-T	500	0.0	0.0	0.0	0.0
5	2,4-D(Sodium salt)	1000	0.0	0.0	0.0	0.0
6	2,4,5-T	1000	0.0	0.0	0.0	0.0
7	2,4-D(Sodium salt)	2000	0.0	0.0	0.0	0.0
8	2,4,5-T	2000	0.0	0.0	0.0	0.0
9	2,4-D(Sodium salt)	3000	0.0	0.0	0.0	0.0
10	2,4,5-T	3000	0.0	0.0	0.0	0.0
11	Check		92.5 <sup>3</sup>	92.5	92.5	92.5

<sup>1</sup>All seeds were placed on blotter paper and held in the germinator at 30°C. for 14 days.

<sup>2</sup>Seeds were soaked in chemical solution for 24 hours and 48 hours respectively.

<sup>3</sup>No chemical treatment, but soaked 3 hours in warm water.

#### Plant Treatments in the Laboratory

Climbing milkweed plants used for laboratory tests were grown from seed and root transplantings in a silty clay loam soil placed in four-gallon open top stone soil pots. The application of spray materials was begun on the first series, Series A, when the plants were 53 days old and had attained a height of 18 to 24 inches. The isopropyl esters of 2,4-D and 2,4,5-T were applied at concentrations

of 1000 and 2000 ppm. The solutions were applied to the foliage of the plants with a bulb-atomizer. The leaves were wetted until the solution formed droplets at the vertex of the leaf.

The foliage was removed from a second series, Series B, of plants 35 days after emergence. The purpose was to increase the number of lateral and secondary roots in proportion to the amount of foliage to determine the extent of translocation of the spray materials. The concurrent regrowth at the end of 45 days was 12 to 18 inches in height, at which time the isopropyl esters of 2,4-D and 2,4,5-T were applied to duplicate plants at concentrations of 50, 100, 250, and 500 ppm.

A third series of plants, Series C, was sprayed when the root system was 120 days old. The primary growth was removed when 60 days old and the spray applications made on the secondary growth at the end of 60 days. Applications of sodium salt of 2,4-D, isopropyl ester of 2,4-D, and sodium salt of 2,4-D plus an emulsible oil, 2 percent by volume, were applied at a concentration of 2000 ppm. Plants included in Series C were treated previously with a commercial preparation of sulphur and copper sulphate for the control of red spider. All plants were washed with water and allowed to dry for three hours prior to applying the 2,4-D compounds.

#### Field Treatments and Results

In June, 1948 a series of 35 100-square-foot plots were established on the farm of Mr. F. Moehlman, located approximately five miles south of Manhattan, Kansas, in Riley County. Corn had

been planted in the field previously and the climbing milkweed was 18 to 24 inches high, typical of that growing in many fields throughout eastern Kansas. The soil was a sandy loam and moist at the time the chemicals were applied. The atmospheric conditions prevailing at the time the chemicals were applied included low wind velocity, high humidity, and an atmospheric temperature of 85° F.

Sodium chlorate and borax were applied to be used as an index in determining the effectiveness of the selective herbicides. These selective sprays included the isopropyl ester of 2,4,5-T, the butyl and isopropyl ester of 2,4-D, the sodium salt of 2,4-D, and ammonium sulphamate. Each treatment was made in triplicate and plant counts were made before and five months after treatment. The concentration of these compounds and the plant counts are shown in Tables 3 and 4.

Previously a series of 24 100-square-foot plots, duplicating those established in June 1948, were established in September 1947, on the farm of Mr. F. Leiser, located approximately 2 miles south of Manhattan, Kansas, in Riley County. Unfortunately before the climbing milkweed plants had emerged the following spring, this area was plowed and seeded to oats and sweetclover. No climbing milkweed plants were observed in this area during March, April, or May of 1948, and since the soil was disturbed on the treated area it was impossible to secure any conclusive results.

Since the check plots showed a marked reduction in population at the end of five months, it was necessary to allow for this natural decrease on these plots treated with chemicals. Therefore, in calculating the percent of kill, as shown in Table 4, on those plots receiving chemical treatment, the reduction due to natural causes

Table 3. Chemicals applied for the control of climbing milkweed.

Treatment number :	Chemical :	Rate of application :
1	Sodium chlorate	1 lb. per 100 sq. ft.
2	Sodium chlorate	2 lbs. per 100 sq. ft.
3	Borax	8 lbs. per 100 sq. ft.
4	Borax	10 lbs. per 100 sq. ft.
5	Ammonium sulphamate	1 lb. per 100 sq. ft.
6	Isopropyl ester 2,4,5-T	2000 ppm <sup>1</sup>
7	Butyl ester 2,4-D	2000 ppm
8	Isopropyl ester 2,4-D	2000 ppm
9	Sodium salt 2,4-D	2000 ppm
10	Sodium salt 2,4-D plus 2% emulsion oil by vol.	2000 ppm
11	Sodium salt 2,4-D plus tributyl phosphate 1:50	2000 ppm

<sup>1</sup>Spray solutions applied at the 2000 ppm level equal approximately 3 pounds of acid per acre.

Table 4. Summary of chemical tests and percent kill of climbing milkweed.

Treatment	Plot no.	Plant counts		Percent kill		Av. Arcsine <sup>4</sup>
		(y) <sup>1</sup>	(n) <sup>2</sup>	(1-Z)	(1-Z) <sup>3</sup>	
1	1	55	10	1.3		6.55
1	18	94	8	53.8		47.18
1	31	113	5	76.0	43.7	60.67
2	8	50	7	23.99		29.32
2	16	69	1	21.94		27.93
2	29	107	0	100.00	48.64	90.00
3	10	58	4	61.63		51.73
3	21	95	1	94.29		76.18
3	28	101	0	100.00	85.30	90.00
4	11	57	0	100.00		90.00
4	19	74	0	100.00		90.00
4	32	133	1	59.19	86.39	50.29
5	5	97	6	66.43		54.59
5	23	86	7	55.81		48.34
5	35	120	8	63.78	62.00	53.00
6	2	81	12	19.57		26.26
6	15	68	7	44.14		41.63
6	26	121	10	55.05	39.51	47.90
7	4	113	7	66.40		54.57
7	13	79	3	79.37		62.99
7	24	91	15	10.30	52.15	18.72
8	6	128	2	15.10		22.87
8	22	84	8	48.30		44.03
8	27	114	8	62.15	41.95	52.03
9	9	71	12	8.00		16.43
9	17	87	18	0.00		0.00
9	34	124	6	73.75	23.21	59.18
10	12	82	4	73.50		59.02
10	20	89	6	63.40		52.77
10	30	122	14	37.65	58.29	37.85
11	3	92	13	23.30		28.86
11	14	119	6	72.65		58.47
11	25	119	5	77.20	57.90	61.48
Check	7	51	7			
Check	33	101	22			

<sup>1</sup>(y)--number of plants before treatments

<sup>2</sup>(n)--number of plants 5 months after treatments

<sup>3</sup> $1-Z = \frac{1-n}{1+y}$  .1842 equals the ratio of average (n) to average (y) for the check plots.

<sup>4</sup>Taken from Table 16.8, Statistical Methods, 4th Edition, Snedecor, George W. 1946.

and the reduction due to chemical treatments both had to be taken into consideration.

In view of the linear relationship found between the sampling mean and the range, it was necessary to use the arcsine (angular) transformation (Snedecor, (29), table 16.8), to study the difference among the chemical treatments. The arcsine values of the percent kill were used in performing the analysis of variance. These figures are shown in Table 4.

There appeared to be no significant difference between any of the chemical treatments five months after the applications were made. The extreme variability between plots treated alike may have been responsible for this nonsignificance. For example, under treatment 1, the percent kill varied from 1.3 to 76.0.

Table 5. Analysis of variance for percent kill of climbing milkweed.

Source of variance	Degrees of freedom	Variance	F	Critical F (P = .05)
Herbicides	10	669.61	1.405	2.60 <sup>1</sup>
Within treatments	22	476.51		
Total	32			

<sup>1</sup> Taken from Table VI, Technique in Agriculture Research, 1939, D. D. Patterson, pp254-255.

Examination of the root system of the treated plants was made 10 months after chemical application and revealed disintegration of the roots 6 to 12 inches below the surface of the soil. There was no evidence of regrowth on any of the plots; however, no conclusions can be made until the amount of regrowth has been determined.

## DISCUSSION

The series of chemical treatments outlined in a foregoing section of this thesis was primarily designed to find a method of controlling climbing milkweed in cultivated fields by the use of herbicides. However, to measure the effectiveness of control with the newer herbicides was rather a difficult problem.

After a study of the factors involved, it was finally decided that by the use of several criteria the effectiveness of the treatments can be determined in relation to one another and to the check. In general, the criteria were population counts, root examinations, and germination tests.

Since seed dissemination is responsible for the spread of climbing milkweed, particularly the establishment of new infestations, a germination study was made to determine the viability and conditions responsible for such germination. Bolley (2) reported that seeds of oats and millet were carried 20 rods in 40 seconds by a 15 mile per hour wind when the seeds were placed on crusted snow. The seed of climbing milkweed, due to its light weight and attached pappus, probably is one of the most efficient modifications for wind distribution.

Germination of the seed of climbing milkweed under varying temperatures and germination media are shown in Table 1. The highest percent germination was shown when the seed was soaked for a period of three hours in warm water, then subjected to a constant temperature of 30°C. for six days. Davis (7) found that seeds of velvet leaf, (Abutilon theophrasti), were still viable after 23 years of

continuous storage in water. Sampson and Parker (28) found the germination of Klamath weed, (Hypericum perforatum), to be higher when submerged in water for 20 days than the unsoaked seed.

The germination of climbing milkweed seed was inhibited when prechilled for five days at 40° F. This indicates that the thin seed coat may allow the seed to be injured readily by low temperatures if not protected adequately by soil or other media.

A reduction in germination was obtained when the seed was subjected to a temperature of 30° C. for 8 hours and 20° C. for 16 hours during a 24 hour period. Germination was also reduced when sand was used as a germinating media. Harrington (17) found that seeds of Bermuda grass and Johnson grass germinate much better with favorable alternations of temperature than at constant temperatures. Cross (5), on germination tests of 29 different species of weed seed germinated on top of blotters and on top of soil, found that alternating temperatures gave higher germination than constant temperatures.

Climbing milkweed seed soaked in a water solution of the sodium salt of 2,4-D at a concentration of 250 ppm for 24 hours, then placed in the germinator at a constant temperature of 30° C. for 14 days showed a reduction in germination of 62.5 percent. Johnson (22) found that mature burs of puncture vine, (Tribulus terrestris), showed an increase in germination when treated with crude-acid sludge and with chlorates. On the other hand, burs treated with petroleum oils, especially diesel oil, failed to germinate. This probably explains the results obtained with climbing

milkweed seed when it was treated with 2,4,5-T. This compound is in an oil carrier. It also should be noted that no seed pods were produced on any of the plants treated with chemicals in the field. Results of germination tests on chemically treated seed are shown in Table 2.

One of the most interesting observations was noted on climbing milkweed plants treated in the laboratory. The isopropyl ester of 2,4-D when applied at a concentration of 50 ppm stimulated bud growth on the roots, but produced no material changes on the foliage. When this compound was applied at a concentration of 250 ppm it produced many small root galls and stimulated bud growth in the leaf axils of the plants. Field applications of the isopropyl ester of 2,4-D at 2000 ppm produced a complete kill of foliage 10 days after treatment. When examined 5 months later, the roots were found to have disintegrated to the first lateral. Below this first lateral, the root system remained alive and intact, and some regrowth was noted.

All milkweed plants treated in the laboratory with the sodium salt of 2,4-D showed little evidence of either foliage or root injury. The addition of oil had a tendency to produce localized burning on the leaves, but in no case caused the plants to die. The kill produced by this compound when applied under field conditions, as shown in Tables 4 and 5, was not significantly different from the check five months after the applications were made. Derscheid (10) reported very little difference in effectiveness of the different formulations of 2,4-D when treatments were made on field bindweed under similar soil and growing conditions.

Observations on climbing milkweed plants treated in the laboratory with the ester formulations of 2,4-D and 2,4,5-T were made 20 hours, 2 days, 8 days, 18 days, and 56 days after the initial treatment.

Observations made 20 hours after treatment revealed moderate curling of the leaves but no loss of chlorophyll. Viehmeyer (31) reported noticeable effects within three hours following treatment on bindweed and that the last living growth was noted 39 days after the initial treatment. Extreme curling of the leaves and localized burning with the dorsal side of the leaves becoming a deep purple in color was evident at the end of 8 days. All of the foliage at 18 days was dead; however, evidence of regrowth from the crown of the plant was noted at this period. Examinations of the roots at the end of 56 days showed that those plants possessing very short lateral roots had decomposed, while those plants possessing rather extensive lateral roots showed evidence of root disintegration only to the first lateral root.

The same curling, localized burning, and purpling of the dorsal side of the leaves were observed in the field which substantiate those determinations made in the laboratory.

There was an apparent difference in the degree of translocation of these chemical compounds between the plants grown in the laboratory and those growing in the field. The chemicals appeared to be translocated greater distances in the field plants. This probably can be attributed to the fact that the lateral roots were considerably deeper in the soil on the plants growing in the field, and the possibility of soil moisture being at a lower depth.

Derscheid (8, 9, 10) reported that high soil moisture is strongly correlated with effective control of field bindweed when treated under favorable growing conditions.

Relatively good translocation and kill were shown by the ester formulations of 2,4-D and 2,4,5-T, while Willard (33) lists climbing milkweed, (Gonolobus laevis), as being resistant to all forms of 2,4-D at all stages of growth. On the other hand Dutton (11) reported that 2,4,5-T gave outstanding results on several Rubus species which previously indicated resistance to 2,4-D.

Ammonium sulphamate, a contact spray, gave a rapid curling of the leaves, and a severe burning of the foliage was noted four days after application. Twelve days after application, 95 percent of the top growth was dead. Twenty-four days after application regrowth was observed throughout the treated plots. This compound did not give a significant reduction in plant population at the rate of 1 pound per 100 square feet.

Borax and sodium chlorate, although producing a 100 percent kill on four plots, were not significantly different from the check as shown in Tables 4 and 5. Sodium chlorate used in a spray solution gave a 95 percent kill of top growth 4 days after application. The low rate of sodium chlorate, 1 pound per 100 square feet, was not effective in retarding regrowth, as some regrowth was noted 24 days after the initial treatment. Some regrowth was also noted on those plots treated with sodium chlorate at the rate of 2 pounds per 100 square feet as shown in Table 4. Sodium chlorate acts as a contact poison on plant tissue. It also is translocated under certain conditions, and will kill plants by root absorption. Robbins,

Crafts, and Raynor (26) state the average rate of application of sodium chlorate to vary from 2 pounds to 10 pounds per square rod depending on the plant species.

Borax was somewhat slower acting than sodium chlorate since moisture was necessary to render the boron available to the plant. The reduction in plant population is shown in Table 4. Crafts, Bruce, and Raynor (3) reported that approximately 2 pounds of borax per square rod gave a 90 percent control of annual vegetation the first year after application, while it required 15 pounds per square rod to give 80 percent control of perennials the first year.

## SUMMARY AND CONCLUSIONS

Climbing milkweed is a serious menace in cultivated fields, especially in row crops. A study of this weed has shown a need for some method of control in the corn and sorghum growing areas of Kansas.

As herbicides offered a possible solution for an efficient and practical method of control, a chemical program was outlined. 2,4-D, 2,4,5-T, ammonium sulphamate, borax, and sodium chlorate were the chemicals chosen for this program.

Seed germination, laboratory studies, and chemical treatments of climbing milkweed were made to determine the effectiveness of these chemicals.

It was found that climbing milkweed germinated best when soaked for three hours in warm water, and then placed on blotter paper in the germinator at a constant temperature of 30° C. for a period of six days.

Seed soaked in a water solution of sodium salt of 2,4-D at a concentration of 250 ppm for 24 hours showed a reduction in germination of 62.5 percent. Seed soaked in 2,4,5-T failed to germinate at all concentrations.

Climbing milkweed plants treated in the laboratory with the isopropyl ester of 2,4-D at 50 ppm and 250 ppm showed evidence of growth stimulation on the roots and axils of the leaves. Laboratory studies of plants treated with the sodium salt of 2,4-D showed little evidence of either root or foliage injury.

Curling of leaves and change of leaf color were noted on the

plants treated with 2,4,5-T and the ester formulations of 2,4-D 20 hours after making the applications.

There appeared to be a greater degree of chemical translocation in the primary vertical roots of the field plants as compared with the laboratory studies. Plants possessing permanent lateral roots showed no evidence of horizontal translocation.

Ammonium sulphamate produced a rapid kill of top foliage; however, regrowth was noticed 24 days after the initial application.

Borax and sodium chlorate gave complete control of climbing milkweed on 4 of the 12 plots treated.

From the studies and observations made on the control of climbing milkweed with chemicals the following conclusions may be stated:

1. Climbing milkweed seed which has absorbed sufficient water to germinate may be killed if exposed to low temperatures for prolonged periods.
2. Spray applications made on the foliage of the plants with any of the chemicals used in this experiment will prevent seed pod formation.
3. Selective herbicides can be used to reduce stands of climbing milkweed, and repeated treatments may give complete control.
4. Ester formulations of 2,4-D and 2,4,5-T appear to be translocated to a greater degree than the sodium salt of 2,4-D.
5. Borax or sodium chlorate may be used to control small or isolated infestations of climbing milkweed, but would not be feasible on large areas because of the long period of soil sterility.
6. Climbing milkweed grows most abundantly in the early spring

and early fall; therefore, spray materials should be applied during these periods.

7. A good crop rotation or the establishment of a sod crop may control climbing milkweed by increasing the competition for soil nutrients.

8. Moisture and temperature conditions favorable for vigorous growth are of primary importance for chemical control of climbing milkweed.

9. The drought which prevailed during the summer and fall of 1948 probably was responsible for the natural reduction of climbing milkweed in the check plots, perhaps rendering it impossible to determine a significant reduction on the treated plots when compared with the check.

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