AN ABSTRACT OF THE THESIS OF

Karin Tanphiphat for the degree of Master of Science in Crop Science presented on April 7,1986 Title: Persistence and Accumulation of Clopyralid (3,6-dichloropicolinic acid) in Soil

Redacted for Privacy

Abstract approved: ______________________

Larry C. Burrill

Field studies were started at Hyslop Farm, Corvallis, Oregon in 1984 to determine the soil persistence of the herbicide clopyralid (3,6-dichloropicolinic acid) under cropping situations. The herbicide was sprayed on bare soil at the proposed use rate of 0.14 kg/ha in the spring and on the same plots at a high rate of 0.56 kg/ha in the summer. Winter wheat (*Triticum aestivum* L. 'Stephen') was seeded in the same fall. Treated plots did not yield differently than untreated plots. Safflower (*Carthamus tinctorius* L.), a crop known to be sensitive to clopyralid, was planted in the spring of 1985 to the area treated with clopyralid in 1984. Safflower grew normally and fresh weights were not reduced.

Greenhouse bioassays were conducted on soil samples collected from two separate sets of plots treated with clopyralid in the fall of 1984 or the spring of 1985. The application rates were 0.56 and 1.12 kg/ha. Lentil

(*Lentilla lens* L.), safflower, and peas (*Pisum sativum* L.) were used as indicator plants. From the plots sprayed in the fall, soil samples were collected at 0, 14, 34, 54, 114, 220, and 287 days after treatment. Clopyralid disappeared faster in the second depth (10 to 20 cm depth) than in the first depth (0 to 10 cm depth). No herbicide was detected in the second depth 220 days after treatment but in the first depth there was sufficient herbicide to cause growth reduction in all of the indicator species. In soil sampled 287 days after applying either 0.56 or 1.12 kg/ha, enough herbicide remained in the first depth to produce slight symptoms on lentil. No herbicide injury was observed on peas or safflower. From plots sprayed in the spring, soil samples were collected 0, 14, 28, and 56 days after treatment. In the spring, clopyralid dissipated more slowly than in the fall, based on the observation that the indicator plants were more severely injured when grown in soil samples collected following the spring application than they were following the fall application.

Adding 2,4-D did not affect clopyralid persistence. Clopyralid and XRM-3785 (clopyralid + 2,4-dichlorophenoxy acetic acid) at the same dosage of clopyralid disappeared from the soil at approximately the same time.

Persistence and Accumulation of Clopyralid (3,6-dichloropicolinic acid) in Soil

by

Karin Tanphiphat

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Master of Science

Completed April 7, 1986

Commencement June, 1986

APPROVED:

Redacted for Privacy

Assistant Professor of Crop Science in Charge of Major

Redacted for Privacy

Head of Department

Redacted for Privacy

Dean of Graduate School

Date thesis presented April 7, 1986

Typed by Karin Tanphiphat

DEDICATION

This thesis is dedicated to my grandfather, Mr. Tien Tanphiphat, who always provides love and guidance to me since I was born and who is the one that has built up the strong foundation of love and happiness in my family.

ACKNOWLEDGEMENT

I would like to express my sincere thanks to my great major professor, Mr. Larry Burrill, for his professional, personal guidance and support through the course of my graduate program and for the critical review of this thesis. Without whose help this task would become very difficult. I am grateful to members of my committee, Dr. Arnold Appleby, Dr. Kenton Chambers, and Dr. Garvin Crabtree for their time and interest. Thanks is extended to the weed people for their help and friendship that made this research more enjoyable. I appreciate the help from Miss Kanya Jariyavaragul who spent a lot of time helping me collecting the soil samples in the wet cold days.

The International Plant Protection Center (IPPC) provided me with valuable experience and with the financial support during the final stage of my study. For this I thank director, Dr. Stanley Miller and all IPPC staff members for their support.

Finally and most importantly, I thank the members of my family at home who provided me an opportunity to come to study in America. The love and encouragement from my parents, grandparents, Choyjea, and my brother and sisters have great contribution to my success and parts of this thesis belong to them.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

PERSISTENCE AND ACCUMULATION OF CLOPYRALID (3,6-DICHLOROPICOLINIC ACID) IN SOIL.

INTRODUCTION

Many foliage-applied herbicides have soil activity. The time that a herbicide remains active in the soil is important. Ideally, a herbicide would persist in the soil long enough to control late-germinating weeds but not long enough to hurt a crop planted in the following season.

The herbicide clopyralid (3,6-dichloropicolinic acid), or DOWCO 290, was introduced in mid 1970's and has shown promise for the control of phenoxy-tolerant brush, woody rangeland species, and deep-rooted broadleaf perennials. A similar herbicide, picloram (4-amino-3,5,6-trichloropicolinic acid) has been available for many years to control most of these problem weeds but its high level of activity and long soil persistence have precluded most crop-land uses.

Though effective on many of the weeds controlled by picloram the duration of clopyralid activity in soil is much shorter. Studies at Davis, California (Dow Chemical Co., 1974) indicated that the half-life of this herbicide is one-quarter that of picloram. The shorter soil-life should allow clopyralid to be used for control of certain problem weeds in small grains.

Most experiments on herbicide persistence in soil have examined the behavior of a single application at the proposed use rate. In some agricultural situations the same herbicide may be applied to the same soil each year for many years; therefore, the herbicide residues might accumulate. The objectives of this experiment were to:

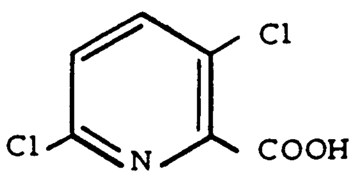
(1) Estimate the length of the soil persistence of clopyralid.

(2) Determine whether a spring and summer application of clopyralid in winter wheat would result in residues harmful to wheat planted later in the same fall or a sensitive crop planted in the next spring.

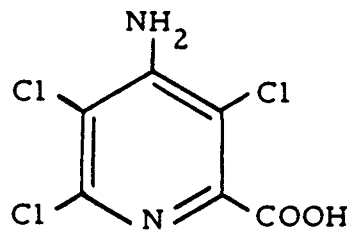
LITERATURE REVIEW

Chemical Properties

Clopyralid is classified as an auxin-type herbicide. Its chemical structure is similar to that of picloram.



3,6-dichloropicolinic acid (clopyralid)



4-amino-3,5,6-trichloro-picolinic acid (picloram)

Clopyralid is a white, odorless crystalline solid with a melting point of 151 C and water solubility of 1000 ppm at 25 C (WSSA Herbicide Handbook,1983). There are two formulations of clopyralid available for experimental work:

XRM-3972 or LONTREL contains 0.36 kg ae/l of the monoethanolamine salt of clopyralid.

XRM-3785 or LONTREL 205 contains 0.06 kg ae/l of clopyralid and 0.24 kg ae/l of 2,4-D (2,4-dichlorophenoxy acetic acid) as alkanolamine salts.

Clopyralid is relatively low in toxicity to animals, as is picloram. Animal feeding studies indicate that clopyralid is readily excreted as the parent compound and is not accumulated in animal tissue (Haagsma 1975).

Selectivity

Broadleaf plants are more sensitive to clopyralid than grasses. Excellent herbicidal activity has been shown against members of Polygonaceae, Compositae,and Leguminosae families (Haagsma 1975).

Peppermint (*Mentha piperita* L.) is reasonably tolerant to clopyralid. Good Canada thistle (*Cirsium arvense* L.) control and high peppermint oil yield was obtained when 0.14 kg/ha of clopyralid was applied 10 weeks prior to harvest and 0.07 kg/ha was applied 2 weeks later (Whitesides and Appleby 1978).

Rapeseed (*Brassica campestris* L. and *Brassica napus* L.) have good tolerance to clopyralid. O'Sullivan and Kossatz (1982) reported rapeseed yield increase, compared to the weedy check, with most of the rates tested.

Olson (1975) found that in wheat, clopyralid caused less growth reduction than 2,4-D or dicamba (3,6-dichloro-o-anisic acid) when applied at the same rate. Brown and Uprichard (1976) showed that, at recommended rates, clopyralid applied to cereals at growth stage from one leaf to second node formation did not result in crop toxicity. But, if treated when the wheat plants were approaching flowering and filling stage, grain yield was reduced by as much as 60% (Keys 1975).

Absorption and translocation

Clopyralid is readily absorbed by the roots and the leaves of treated plants. O'Sullivan and Kossatz (1984) reported that absorption of clopyralid by Canada thistle was rapid and continued up to 48 hours after treatment, at which time half of the absorbed herbicide had translocated out of the treated leaves. Similar results were obtained by Devine and Vanden Born (1985) who reported that 99% of the applied clopyralid was absorbed by the treated leaves 144 hours after application and translocation was so rapid that shoot regrowth was reduced when the treated shoot was cut off 24 hours after treatment.

Turnbull and Stephenson (1985) observed that after the foliage treatment, a significant amount of clopyralid was translocated to the distal foliage and roots where some was exuded from the latter. He suggested that greater acropetal mobility and reduced root exudation were responsible for greater effectiveness of this herbicide against Canada thistle as compared to 2,4-D. These results were in contrast to those of O'Sullivan and Kossatz (1984) who found that little clopyralid was translocated to the roots. He suggested that the sensitivity of the root rather than the effective transport was more important for effective root kill.

Clopyralid can also be taken up by plant roots. Bovey and Mayeux (1980) found more herbicide in roots of plants receiving soil treatment than foliage treatment.

Metabolism in plants

The metabolic fate of clopyralid has not been completely explained. It appears that it remains in plants as unchanged chemical (WSSA Herbicide Handbook 1983). The persistence of clopyralid in plants has been reported by Brown and Uprichard (1976). In their study, the chemical was not metabolized in green plants, and application during adverse growing conditions often lead to satisfactory weed control once active growth recommenced. Hall and Vanden Born (1983) reported that clopyralid may be converted to a carboxylic acid amide derivative in rapeseed. Turnbull and Stephenson (1985) suggested that differences in metabolism in plants did not seem to be an important factor in the greater efficacy of this herbicide over 2,4-D.

Mixture with other herbicides

The mixture of two or more herbicides may increase the efficiency of weed control. Formulated mixtures of clopyralid and phenoxy herbicides have been developed to widen the spectrum of broadleaf weed control in cereals.

Naish (1975) observed no crop damage when clopyralid at doses from 0.14 kg/ha to 0.28 kg/ha in combination with phenoxy herbicides was applied to wheat and barley (*Hordeum distichon* L.)between three-leaf stage and the jointing stage. Olson (1975) observed that XRM-3785 at 0.14 + 0.56 kg/ha applied at the four-tiller stage of wheat caused a reduction in grain yield when compared to clopyralid at 0.14 kg/ha and 2,4-D at 0.56 kg/ha. Brown and Uprichard (1976) suggested that application time was dependent upon normal recommendations for the phenoxy herbicide in the mixture components and also on the stage of weed growth.

O'Sullivan and Kirkland (1984) reported that the mixture of clopyralid at 0.14 to 0.3 kg/ha with diclofop methyl (methyl 2-(4-(2,4-dichlorophenoxy) phenoxy) propanoate) at 0.7 kg/ha or difenzoquat (1,2-dimethyl-3,5-diphenyl-1H-pyrazolium methyl sulfate) at 0.84 kg/ha provided good control of wild oat (*Avena fatua* L.) and Canada thistle in wheat. They showed that the mixtures of these herbicides increased yields over the untreated control, and yields equal to those obtained with diclofop methyl or difenzoquat alone.

Fate in the soil

Clopyralid has a pKa of 2.33 and hence exists in the anion form in most soils. The mobility of this herbicide in soil is therefore expected to be high. Naish (1975) suggested that because of its low pKa, it could be subjected to leaching. He also suggested that rainfall was a major factor in the disappearance of this herbicide from soil.

Clopyralid is not readily adsorbed in the soil. But the adsorption increases with an increase in organic carbon in the soil (Pik et al. 1977). It was reported that adsorption of picloram increases with an increase in soil organic matter or a decrease in soil pH (10, 20, 34).

The experiment reported by Pik et al. (1977) demonstrated that the degradation of clopyralid was faster in natural soil than in sterilized soil. They suggested that degradation of clopyralid occured mainly by microbial action.

Soil persistence

The persistence of a herbicide depends on climatic conditions and soil components.

Farrow and Cheng (1985) found that the degradation process was slowed by drying and water-logging in soil. Pik et al.(1977) reported that degradation of clopyralid was fastest in moist soil. They also observed great reduction in degradation during both dry and cold periods. Factors favorable for microbial growth promote degradation. Most important are warm temperatures and a favorable moisture content of the soil.

Soil components also influence the degradation rate of herbicides. In high organic matter content soil, clopyralid persists longer because the adsorption prevents the breakdown of herbicides by the microorganisms.

Several studies showed that clopyralid has a shorter life in soil than picloram. Clopyralid degrades at a medium to fast rate with an average half-life range of 12 to 70 days in a wide range of soils across the US. Periodic bioassays following field applications of up to 0.56 kg/ha resulted in no injury to susceptible crops the following year (WSSA Herbicide Handbook 1983). Farrow and Cheng (1985) found that the degradation rate of clopyralid was independent of the initial concentration in the soil, at 0.016 ± 0.002 μg/g/week.

On a loam soil containing 1% organic matter in California, soybeans (sensitive to clopyralid) could be planted 16 weeks after application of 0.31 kg/ha of clopyralid without injury (Haagsma, 1975). Naish (1975) found no residue of clopyralid in soil sampled 25 days after treating with 0.45 kg/ha. Miller and Alley (1985) reported that little or no injury was observed when corn (Zea mays L.) , pinto bean (Phaseolus sp.), spring wheat, spring barley, or oat (Avena sativa L.) were seeded 6 to 8 months after clopyralid application at 0.3 kg/ha to 0.6 kg/ha. Cseh (1976) demonstrated that when soybeans were seeded 70 days after the application of clopyralid + 2,4-D at 0.12 + 0.45 kg/ha, stand and yield were unaffected. Olson (1975) observed no injury symptoms on soybeans (Glycine max L.), safflower (Carthamus tinctorius L.)and peas (Pisum sativum L.) when they were planted one year after a single application of XRM-3785 at 0.28 + 1.12 kg/ha in winter wheat. When safflower was planted in the same soil in the greenhouse they found that there was not enough XRM-3785 in the soil to cause safflower injury 16 weeks after the treatment.

Winter wheat culture in Western Oregon

In Western Oregon, farmers may plant wheat in the same field year after year. This monoculture leads to increased populations of weeds with life cycles similar to wheat. The farmers may reduce the problem by rotating the crops. If spring crops are used for rotation, the wheat stubble will be left over winter before the rotation crops are planted in the following spring. If perennial broadleaf weeds are a problem the field may be sprayed soon after wheat harvest and before the weeds are defoliated by frost. Since there is no crop in the field herbicides such as dicamba, 2,4-D, and clopyralid may be applied at optimum rates for control. At these high rates residual toxicity to spring planted crops becomes a concern.

Bioassay

Bioassay is the measurement of a biological response by a living organism to determine the presence or estimate the concentration of a chemical in a substrate. The biological assay is employed for various proposes, eg. residue studies, leaching experiments, establishment of degradation curves and for the determination of the amount of herbicide available to the plant (Hurle 1977). In herbicide research, bioassays may be more meaningful than chemical assays because they measure the amount of herbicide that is biologically active. In addition, bioassays do not require sophisticated methods or equipment. Selection of the proper indicator plant is important to the effectiveness of a bioassay. The species to be used must responsed sufficiently to low herbicide concentrations. If the concentration range is large, two or more species that exhibit different levels of sensitivities may be necessary.

Many criteria can be used to measure plant response. These are shoot-root fresh weight or dry weight, shoot height, plant water consumption, and oxygen or carbon dioxide evolution. Some researchers also use a visual rating system in evaluating plant response. The data obtained in biological assays are usually expressed as direct measurements or as percent of the control plants. The amount of the herbicide in the unknown sample is usually estimated by comparing symptoms with those on plants growing in a known concentration of the same herbicide.

FIELD EXPERIMENTS

General Materials and Methods

In the spring of 1984, experiments were started at Hyslop Farm, Corvallis, Oregon, to determine the persistence and accumulation of clopyralid in soil under cropping conditions.

Soil at Hyslop Farm is a Woodburn silt loam (fine-silty, mixed, mesic Aquultic Argixeroll). This soil is moderately well drained. The mechanical analysis of this soil in the Ap horizon (0-18 cm.) is 9% sand, 70% silt, and 21% clay with 3% organic matter, pH of 5.4, and cation exchange capacity of about 15.5 meq/100gm.

The experiments were conducted using a randomized complete block design with five treatments and four replications. The plot size was 3.0 by 7.6 m. All treatments were applied with a bicycle-wheel plot sprayer using a 2.13-meter boom with 8002 flat-fan nozzles and at a pressure of 276 KPa in approximately 234 l of water per hectare.

The plot plan and the plot layout of the field bioassay experiments are presented in Table 1 and Figure 1, respectively.

The treatments applied were :

1. Clopyralid 0.14 kg/ha spring 1984

   plus

   Clopyralid 0.28 kg/ha summer 1984

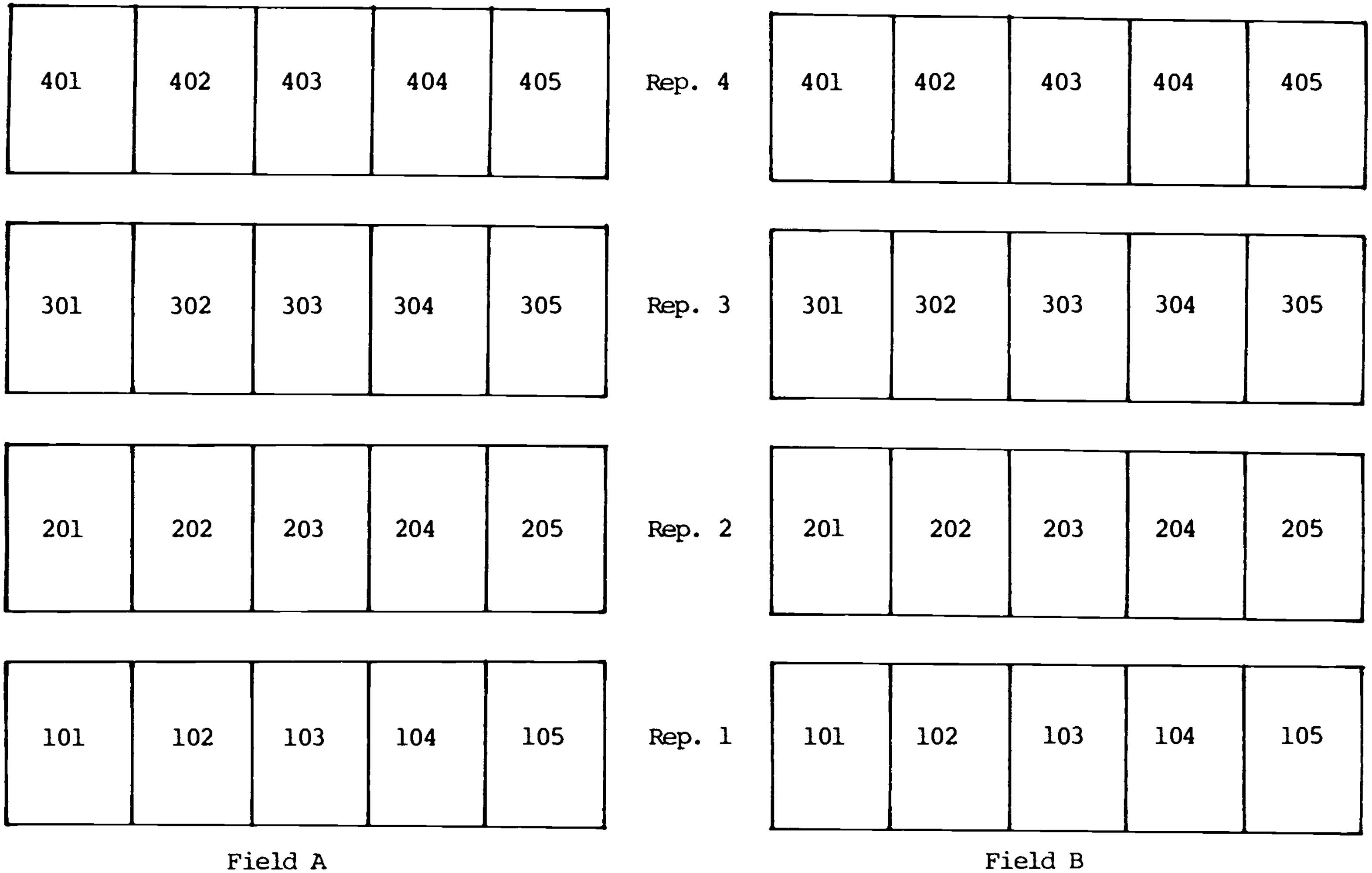


Figure 1. Plot lay-out of the field bioassay experiments at Hyslop Farm, Oregon.

Table 1. The two-year plot plan of the field bioassay experiments.

Date	Field A	Date	Field B
May 17,1984	lower rate of each treatment applied to bare soil	May 17,1984	lower rate of each treatment applied to bare soil
Aug.15,1984	higher rate of each treatment applied to bare soil	Aug.15,1984	higher rate of each treatment applied to bare soil
Oct.29,1984	winter wheat seeded	-	plots left over the winter
May 3,1985	lower rate of each treatment applied to wheat	May 14,1985	safflower seeded
July 23,1985	wheat harvest	Aug.1,1985	safflower harvest
	end of the first year experiment		
Sep.10,1985	higher rate of each treatment applied to wheat stubble	Sep.10,1985	higher rate of each treatment treated to the plots
-	plot left over the winter	Oct. 1985	winter wheat seeded
May 1986	planted to a sensitive crop		
Aug. 1986	crop harvest	Aug. 1986	wheat harvest
	end of the second year experiment		

2. Clopyralid 0.14 kg/ha spring 1984

plus

Clopyralid 0.56 kg/ha summer 1984

3. XRM-3785 0.14 + 0.56 kg/ha spring 1984

plus

XRM-3785 0.56 + 2.24 kg/ha summer 1984

4. 2,4-D 0.56 kg/ha spring 1984

plus

2,4-D 2.24 kg/ha summer 1984

5. check

Both applications of each treatment were applied to Field A and Field B on bare soil. Field A was then planted to wheat in the fall and Field B was left over the winter before it was planted to safflower in the spring of 1985. These two herbicide applications simulated those used in a cropping situation, where the low rate might be applied to the wheat crop and the high rate might be applied to weeds in the wheat stubble.

In the spring of 1985 the lower rates of each treatment were applied to Field A when the wheat was in the pre-jointing stage. The higher rates of each treatment were applied to stubble after wheat harvest in the summer of 1985. The plots were left over the winter. The plots will be planted to a sensitive broadleaf crop in the spring of 1986.

In the summer of 1985 the higher rates of each treatment were applied to Field B after safflower harvest. The plots were planted to wheat in the fall of 1985.

Effect of herbicide residue on winter wheat (field A-1984)

The objective of this experiment was to determine if clopyralid, applied at the proposed use-rate on wheat in the spring and at a higher rate on wheat stubble after harvesting, would result in residue harmful to wheat planted the same fall.

Materials and methods

The first applications of each treatment were applied on May 17,1984 and the second applications were applied on August 15,1984. Before planting the wheat, paraquat at 0.56 kg/ha was sprayed to control the small weeds. Winter wheat (*Triticum aestivum* L. 'Stephens') was seeded on October 29,1984, at the seeding rate of 112 kg/ha in rows 17.8 cm apart with a Nordston drill. On March 1,1984, when the wheat had one to two tillers, 336 kg/ha of 40-0-0-6 (N-P-K-S) fertilizer was broadcast. On April 5,1984, bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) + MCPA (2-methyl-4-chlorophenoxyacetic acid) at 0.42 + 0.42 kg/ha was applied for control of certain broadleaf weeds. The wheat was harvested on July 23,1985 with a Hege self-propelled plot combine.

In the spring of 1985 the lower rate of each treatment was applied when the wheat was in pre-jointing stage. The higher rate of each treatment was applied on wheat stubble on September 10,1985 after the wheat had been harvested. The plots were then left over the winter. A sensitive crop, probably safflower, will be planted into these plots in the spring of 1986. These two applications were part of the long-term persistence study to determine if there is accumulation of clopyralid under cropping conditions over 2 years. The results are not included in this report.

High rainfall in October 1984 resulted in poor germination of the wheat seeds, especially in the middle rows of the plots. Grain yields were taken from only the two outer rows on each side of each plot in this trial.

Supplementary trial

Because of research problems with the previously discussed trial and to determine if clopyralid was harmful to wheat planted soon after spraying, a supplementary trial was conducted.

Materials and Methods

To simulate possible accumulation of clopyralid from two applications as used in the original trial, the extremely high rate of clopyralid (1.12 kg/ha) was included in this experiment. The treatments applied were :

1. Clopyralid 0.28 kg/ha
2. Clopyralid 0.56 kg/ha
3. Clopyralid 1.12 kg/ha
4. XRM-3785 0.56 + 2.24 kg/ha

5. 2,4-D 2.24 kg/ha

6. check

All the treatments were applied on December 5,1984. On January 9,1985, the plots were planted to wheat in 25-cm. row spacing. On March 26,1985, 224 kg/ha of 40-0-0-6 (N-P-K-S) fertilizer was broadcast. The plots were harvested on August 7,1985.

Effect of herbicide residue on rotation crops (field B-1984)

The objective of this experiment was to determine whether clopyralid applied at proposed use rates on wheat in the spring and at higher rates on wheat stubble after harvest would leave residues to harm a sensitive broadleaf crop planted in the next spring.

Materials and methods

The first application of each treatment was applied on May 17,1984 and second applications were applied on August 15,1984. The plots were then left over the winter. In order to simulate normal conditions, no weed control measures were used. The plots were roto-tilled prior to planting the safflower. On May 14,1985, safflower was seeded with a Planet-jr. with row spacing of 30 cm. Irrigation water was supplied through sprinklers as needed. On July 1,1985, 112 kg/ha of urea fertilizer was strip-banded over the safflower rows with a Gandy fertilizer spreader. The plots were kept weed free by hand-hoeing.

The safflower was harvested on August 1,1985 by a Carter plot harvester and fresh-weights were measured.

On September 10,1985, the high rates of each treatment were applied to the plots after the safflower was harvested. These applications were part of the study to determine the effect on wheat of several applications of clopyralid in 2 years. The plots were planted to wheat in the fall of 1985.

Results and Discussion

Effect of herbicide residue on winter wheat

Results for the original trial are presented in Figure 2 and Appendix Tables 1 and 2. There were no significant differences among yields from treatments applied on this trial. However, the yield from plots treated with XRM-3785 tended to be higher than others. The higher yields may have resulted from the broader spectrum of weed control resulting from the addition of 2,4-D. In summer of 1984, plots treated with XRM-3785 had fewer weeds, especially shepherdspurse (*Capsella bursa-pastoris* L.) and wild turnip (*Brassica campestris* L.). This may be partially responsible for the higher yield in the XRM-3785 treatments.

Supplementary trial

Yield results from the supplementary trial are presented in Figure 3 and Appendix Tables 3 and 4. There were no significant differences in yields even though clopyralid at 1.12 kg/ha resulted in yields lower than the other treatments. In real situations the rates used would not be as high as 1.12 kg/ha. Another factor to consider is that the interval between herbicide application and wheat planting was only 36 days. This is shorter than expected under normal production practices. Had the time interval been longer, more herbicide would have dissipated and yield reduction might not have occurred.

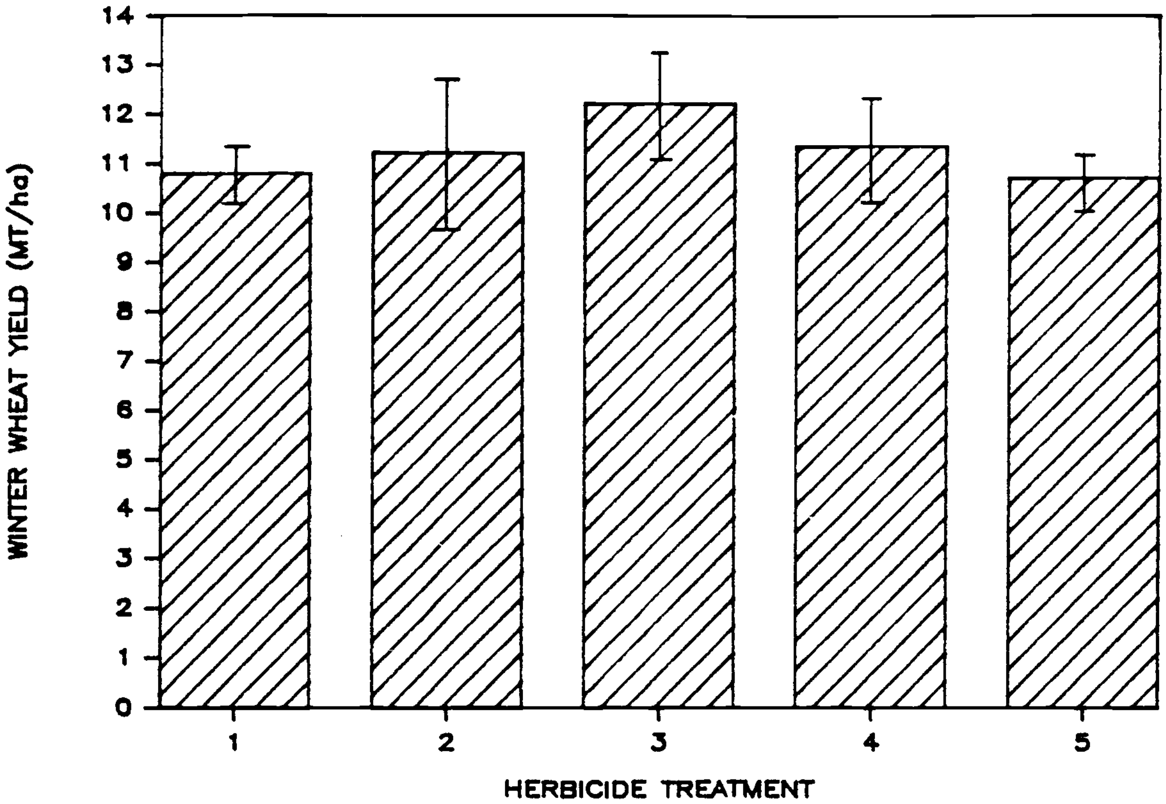


Figure 2. Winter wheat grain yield on July 23,1985 as influenced by residue from different herbicide treatments (original trial).

Treatment 1	clopyralid	0.14 kg/ha	May 17,1984	
		plus		
	clopyralid	0.28 kg/ha	August 15,1984	
Treatment 2	clopyralid	0.14 kg/ha	May 17,1984	
		plus		
	clopyralid	0.56 kg/ha	August 15,1984	
Treatment 3	XRM-3785	0.14 + 0.56 kg/ha	May 17,1984	
		plus		
	XRM-3785	0.56 + 2.24 kg/ha	August 15,1984	
Treatment 4	2,4-D	0.56 kg/ha	May 17,1984	
		plus		
	2,4-D	2.24 kg/ha	August 15,1984	
Treatment 5	check			

Both applications of each treatment were sprayed on bare soil. The plots were planted to wheat on October 29,1984. The vertical bars represent plus or minus standard error of the mean. There were no significant differences in grain yield among different treatments.

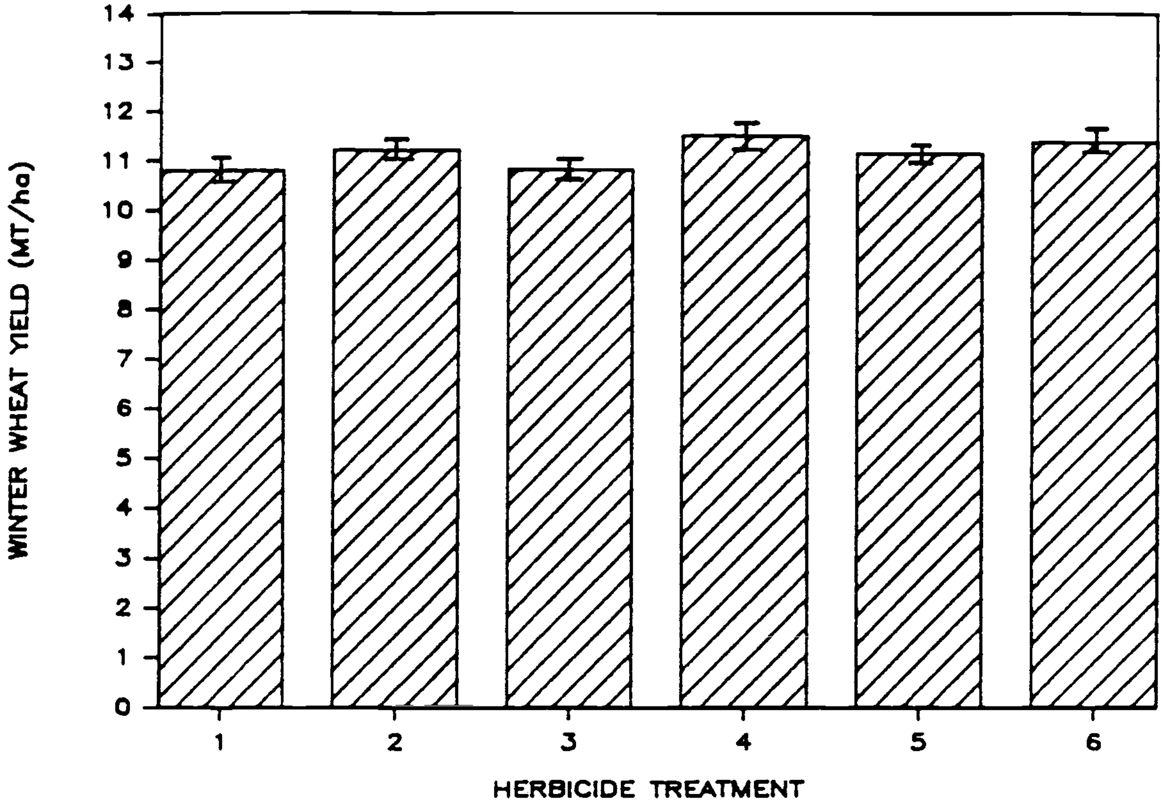


Figure 3. Winter wheat yield on August 7,1985 as influenced by residue from different herbicide treatments applied on December 5,1984 (supplementary trial). The wheat was seeded on January 9,1985.

Treatment 1	clopyralid	0.28 kg/ha
Treatment 2	clopyralid	0.56 kg/ha
Treatment 3	clopyralid	1.12 kg/ha
Treatment 4	XRM-3785	0.56 + 2.24 kg/ha
Treatment 5	2,4-D	2.24 kg/ha
Treatment 6	check	

The vertical bars represent plus or minus standard error of the mean. There were no significant differences in yield among different treatments.

Effect of herbicide residue on rotation crop

Results of the long-term residue trial are presented in Figure 4 and Appendix Tables 5 and 6. There were no significant differences in fresh weights of safflower planted 9 months after the second application of clopyralid. Most herbicide treatments yielded more than the check. The better weed control by the herbicides during the winter may have reduced the uptake of nutrients by weeds. Thus more nutrients would have been available to the safflower.

Precipitation and average temperatures during the period of these experiments are presented in Table 2.

Under Willamette Valley climatic conditions, clopyralid at a proposed use rate applied in spring and at a high rate applied in summer did not result in residues harmful to wheat planted in the same fall or to a sensitive crop planted the following spring. Rainfall may be the main factor contributing to clopyralid disappearance from the soil. Additional research should be conducted to study the persistence of clopyralid under lower rainfall conditions.

Several researchers saw no evidence that repeat treatment of several herbicides over several years led to the accumulation of residue in the soil (8, 13, 15). However, research should be continued to study the persistence of successive applications of clopyralid, over several years.

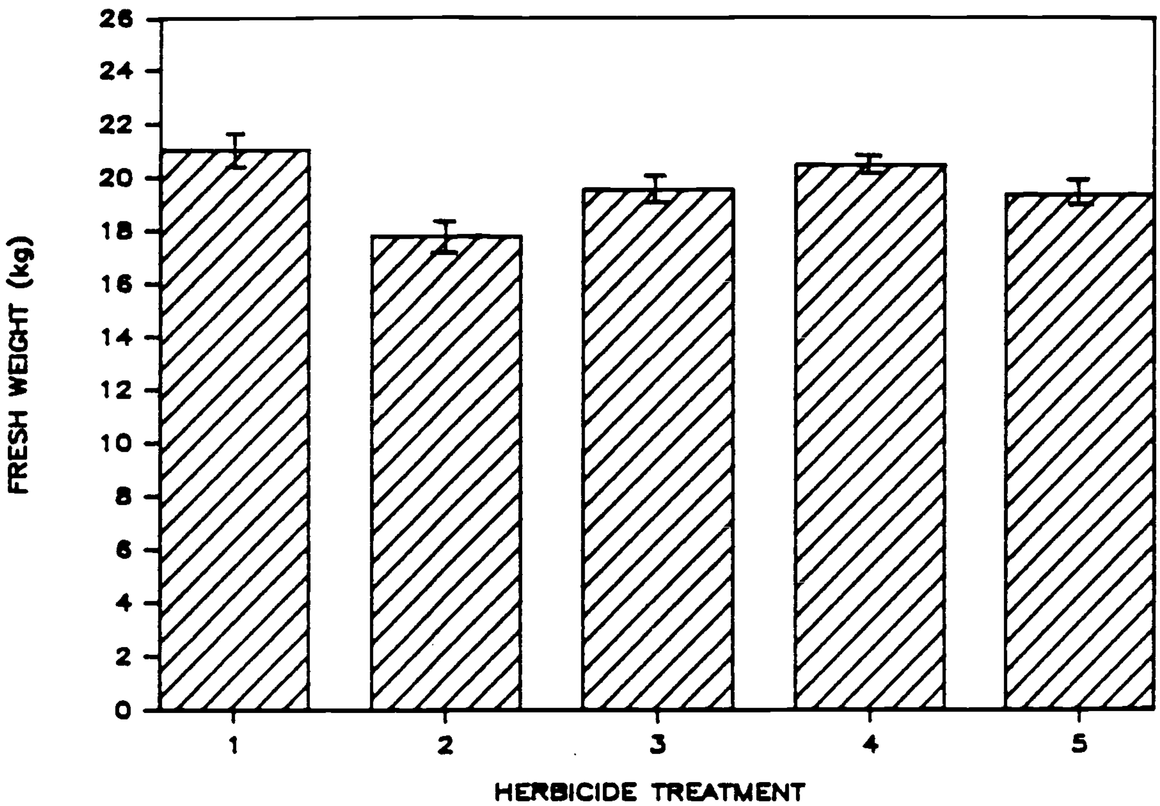


Figure 4. Safflower fresh weights on August 1,1985 as influenced by residue from different herbicide treatments.

Treatment 1	clopyralid	0.14 kg/ha	May 17,1984
		plus	
	clopyralid	0.28 kg/ha	August 15,1984
Treatment 2	clopyralid	0.14 kg/ha	May 17,1984
		plus	
	clopyralid	0.56 kg/ha	August 15,1984
Treatment 3	XRM-3785	0.14 + 0.56 kg/ha	May 17,1984
		plus	
	XRM-3785	0.56 + 2.24 kg/ha	August 15,1984
Treatment 4	2,4-D	0.56 kg/ha	May 17,1984
		plus	
	2,4-D	2.24 kg/ha	August 15,1984
Treatment 5	check		

Both applications of each treatment were applied on bare soil before the plots were planted to safflower on May 14,1985. The vertical bars represent plus or minus standard error of the mean. There were no significant differences in fresh weights of safflower among different treatments.

Table 2. Rainfall and average temperatures during the period of experiment at Hyslop Farm, Corvallis, Oregon.

Month		Rainfall (mm)	Avg. Temperature (degree Celsius)
1984			
May	1st application	93.2	11.7
June		110.2	14.6
July		5.1	18.9
August	2nd application	0	17.4
September		18.8	16.1
October	wheat planted	118.1	10.2
November		344.2	12.3
December		197.4	3.3
1985			
January		6.4	1.8
Feburary		92.7	4.6
March		125.5	6.4
April		26.7	11.1
May	safflower planted	23.9	12.8
	Total	1142.9	

BIOASSAY EXPERIMENTS

General Materials and Methods

In the fall of 1984 and the spring of 1985, bioassay experiments were started to measure the persistence of clopyralid in the soil. Field plots were conducted at Hyslop Farm, Corvallis, Oregon, by using the randomized complete block design with six treatments and four replications. The plot size was 3.1 by 7 meters. All herbicide treatments were broadcast-sprayed with a bicycle-wheel plot sprayer using a 2.4-meter boom, and 8002 flat fan nozzles at a pressure of 276 KPa. The spray volume was 234 liters per hectare. The herbicide treatments were applied to bare soil. The treatments were.

1. Clopyralid 0.56 kg/ha
2. Clopyralid 1.12 kg/ha
3. XRM-3785 0.56 + 2.24 kg/ha
4. XRM-3785 1.12 + 4.48 kg/ha
5. 2,4-D 4.48 kg/ha
6. Check

A scraper-type soil sampler with a diameter of 8.3 cm was used to collect soil samples from a 2 by 5.2 m area in the center of each plot. Sampling was planned for immediately after application, and 14, 28, 56, 112, or 224 days after treatment. The actual sampling dates depended on the moisture content of the soil. The sampling depths were

0 to 10 cm and 10 to 20 cm. Two samples were collected from each depth and then mixed to form a composite sample for each depth. The plots were kept relatively weed-free by occasional mowing.

At each sampling date, the soil samples were bioassayed immediately after they were collected or they were kept in the freezer for up to 2 weeks before the assays were started. The soil samples were planted to the indicator plants in the greenhouse in 7.6 by 7.6 cm pots. Before planting, the soil was screened through a 4-mm sieve. If the soil was too wet, it was air-dried on the greenhouse bench for several days before it was assayed.

The pots were placed in drainage pans and sub-irrigated as needed. The pots were maintained on the greenhouse bench under high intensity fluorescent lamps turned on for 12 hours each day. Greenhouse temperatures were maintained near 20 C. Three weeks after planting, the plants were evaluated by using the rating system (Frans and Talbert, 1977) presented in Table 3. Then the plants were harvested at the soil level and shoot fresh-weights were taken.

Standard Curve Experiments

Before establishing the bioassay experiments, a greenhouse study was conducted to assess the soil activity of clopyralid. Peas, greenbean (*Phaseolus vulgaris* L.), soybean , safflower (*Carthamus tinctorius* L.), lentil

Table 3. The 0 to 100 rating system following Frans and Talbert (1977).

Rating	Description of main categories	Detailed description
0	No effect	No crop reduction or injury
10		Slight crop stunting
20	Slight effect	Some crop stunting or stand loss
30		Crop injury more pronounced, but not lasting
40		Moderate injury, crop usually recovers
50	Moderate effect	Crop injury more lasting, recovery doubtful
60		Lasting crop injury, no recovery
70		Heavy crop injury and stand loss
80	Severe effect	Crop nearly destroyed, a few surviving plants
90		Only occasional live crop plants left
100	Complete effect	Complete crop destruction

(*Lentilla lens* L.), barley (*Hordeum vulgare* L.), and wheat (*Triticum aestivum* L.) were tested for sensitivity to clopyralid in the soil. From this experiment peas, safflower, and lentil were selected as the indicator plants. Among these three species the degree of sensitivity increased from peas, safflower, and lentil, respectively.

Materials and Methods

Soil collected from an untreated area near the experimental site was treated with clopyralid at concentrations of 0.0039, 0.0078, 0.0156, 0.03125, 0.0625, 0.125, 0.25, and 0.5 parts per million of the air dry soil. The soil was sprayed and mixed thoroughly in a soil tumbler. After spraying, soil at each concentration was placed in three plastic pots with approximately 300 gm (air-dry weight) per pot. Four, four, and six pre-germinated seeds of peas, lentil, and safflower, respectively, were then planted into each pot 1.0 cm deep. There were two replications per treatment.

The standard curves were conducted every time the soil samples from the field plots were assayed. They were put into the same environment as the assayed samples.

Figure 5 shows the typical response of the indicator plants to various concentrations of clopyralid. Standard curve data of clopyralid for each species over different dates are presented in Appendix Table 7, 8, 9, 10, 11, and

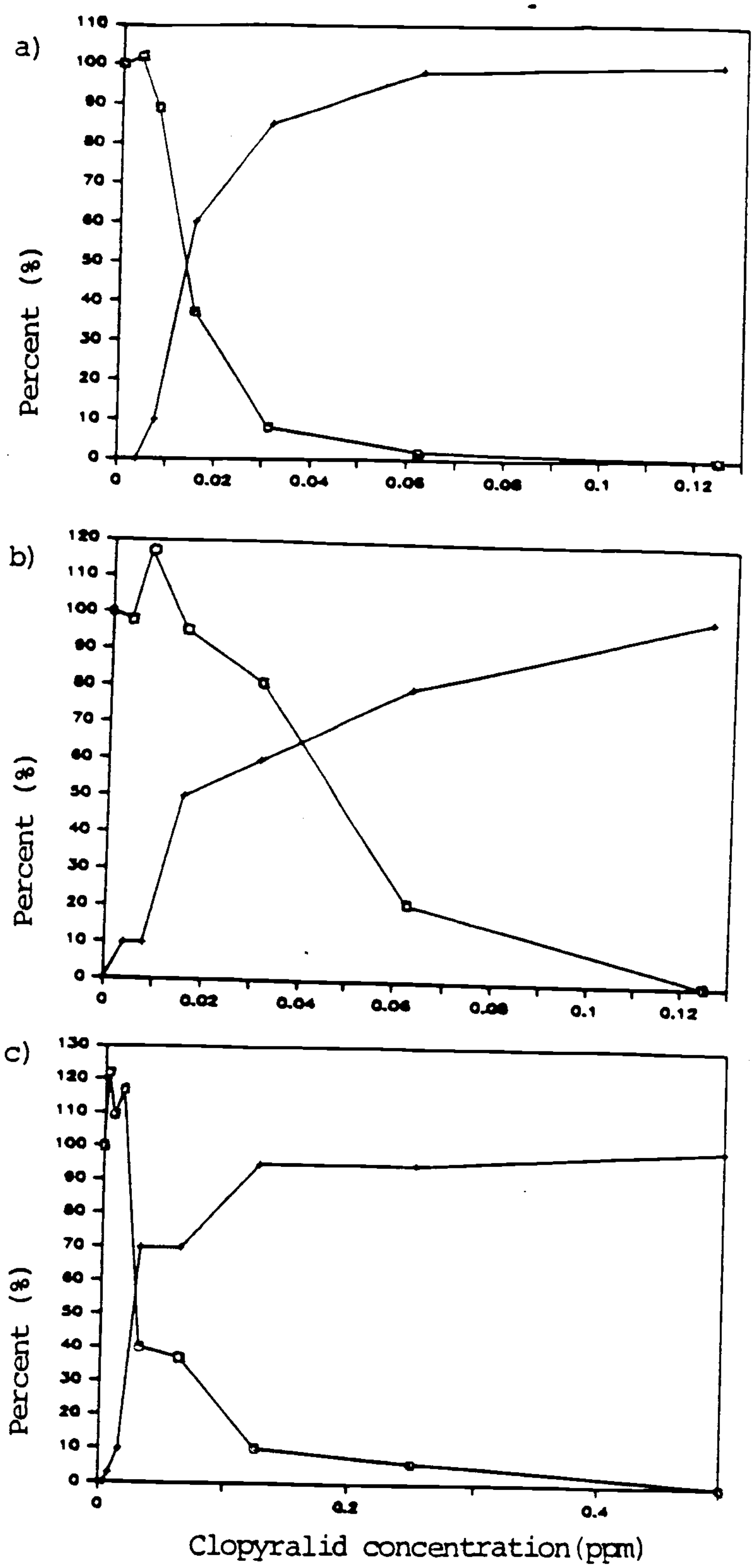


Figure 5. Dose-plant response relationship of lentil (a), safflower (b), and peas (c), grown in soil treated with various concentrations of clopyralid

+ Visual injury

□ Fresh weight as percent of check

12. Results were fairly consistent; however, the sublethal[a] and lethal concentrations[b] were not always the same. This is shown in Table 4. At lower clopyralid concentrations, injury was usually more obvious in lentil than in the other two species.

Table 4. The sublethal and lethal concentrations in ppm of clopyralid on the standard curve plants at several dates based on visual injury.

Date	Lentil		Safflower		Peas	
	Sub-leth.	Leth.	Sub-leth.	Leth.	Sub-leth.	Leth.
1	-	-	-	-	-	-
2	0.0078	0.125	0.0039	0.125	0.0078	0.25
3	0.0039	0.125	0.0039	0.125	0.0078	0.25
4	0.0039	0.25	0.0039	0.125	0.0078	0.25
5	0.0039	0.125	0.0156	0.5	-	-
6	0.0078	0.0625	0.0039	0.5	0.0156	0.25
7	-	-	-	-	-	-[c]

a Concentration at which the herbicide symptoms can be detected from the indicator plant.

b Concentration at which the indicator plant is completely killed.

c No evaluation was made.

Fall Bioassay

Materials and Methods

Treatments were applied on September 12, 1984. Soil samples were collected 0, 14, 34, 54, 114, and 220 days after treatments (DAT). Because herbicide symptoms were observed on the indicator plants 220 DAT, another soil sample was taken at 287 DAT. The soil samples were assayed in the greenhouse by the procedures described in the general materials and methods.

Spring Bioassay

Materials and Methods

The treatments were applied on April 4, 1985. Soil samples were collected 0, 14, 28,and 56 days after treatment. The assay procedures were similar to those described for the fall bioassay.

Supplementary Assay

It was observed in the spring of 1985 that there were fewer common groundsel (*Senecio valgaris* L.) plants in peppermint plots treated with clopyralid in the fall of 1984 as compared to the check plots. Bioassay experiments were conducted to determine if the lower density of common groundsel was due to the residual activity of clopyralid. Soil at this location is Newberge silt loam with 4.4% organic matter and pH of 4.4.

Materials and Methods

On April 22, 1985, soil samples were taken from a peppermint trial located at North Lebanon, Oregon. They were taken from the plots treated with clopyralid on September 26, 1984, at the rates of 0, 0.14, 0.28, and 0.56 kg/ha. The sampling depth was 0 to 10 cm. The soil samples were planted to the indicator species in the greenhouse. There were three replications for each sample.

Evaluation of results

The concentrations of clopyralid in the soil samples were estimated by comparing the symptoms of the indicator plants growing in the treated soil with the plants of the standard curve.

Results and Discussion

Fall Bioassay

Estimated concentrations of clopyralid residues in soil, based on bioassays of soil samples at different dates, are shown in Appendix Tables 13 and 14. Attempts were made to determine the concentrations of clopyralid by using fresh weights of test species. However, the results did not seem to accurately indicate herbicide levels, especially at low clopyralid concentrations. Plants grown in soil collected 220 DAT were obviously injured, but fresh weights were not different (Appendix Table 15). With hormone-type herbicides, affected plants may weigh as much as, or even more than, untreated plants. Therefore, visual evaluations of injury symptoms; i.e. growth malformations, epinasty, etc. were used to estimate soil residue levels.

The initial treatment of 1.12 kg/ha is approximately equivalent to a concentration of 0.75 ppm by weight if mixed uniformly in the surface 10 cm of the soil. Disappearance curves obtained by plotting the data from Appendix Tables 13 and 14 are shown in Figures 6 and 7, respectively. In the first three sampling dates the herbicide concentration in the first depth (0-10cm) could not be estimated because all of the indicator species were killed. As indicated by the dotted lines in Figures 6 and 7, the curve may rapidly decline from the initial concentration and intersect the first point of the first depth on those graphs. The concentrations remaining 54 DAT were all within the detectable range of the indicator species.

Rainfall during the experiment was 900 mm. The disappearance patterns detected by each indicator species were similar for both rates of application. A significant amount of clopyralid had disappeared from the first depth (0-10 cm) at 54 DAT. Highest clopyralid concentration also was detected in the second depth (10-20 cm) at this sampling date. Precipitation during this period was 224 mm. This was enough to leach some of the clopyralid from the first depth. As the herbicide rate increased, the detectable clopyralid in both depths increased. After 54 days, degradation of clopyralid in the first depth slowed. The slow degradation coincided with the winter period. Cold is known to limit the activity of microorganisms. Pik et al.(1977) observed that clopyralid degradation was greatly retarded after having been in the soil over a winter period. They suggested that clopyralid became strongly adsorbed over a winter period, making it unavailable for microbial degradation.

Clopyralid disappearance was faster in the second depth than in the first depth. No herbicide was detected in the second depth 220 DAT, but the amount remaining in the first depth was enough to hurt all of the indicator species. At 287 DAT, clopyralid in the first depth was detected by lentil at both rates of application but the

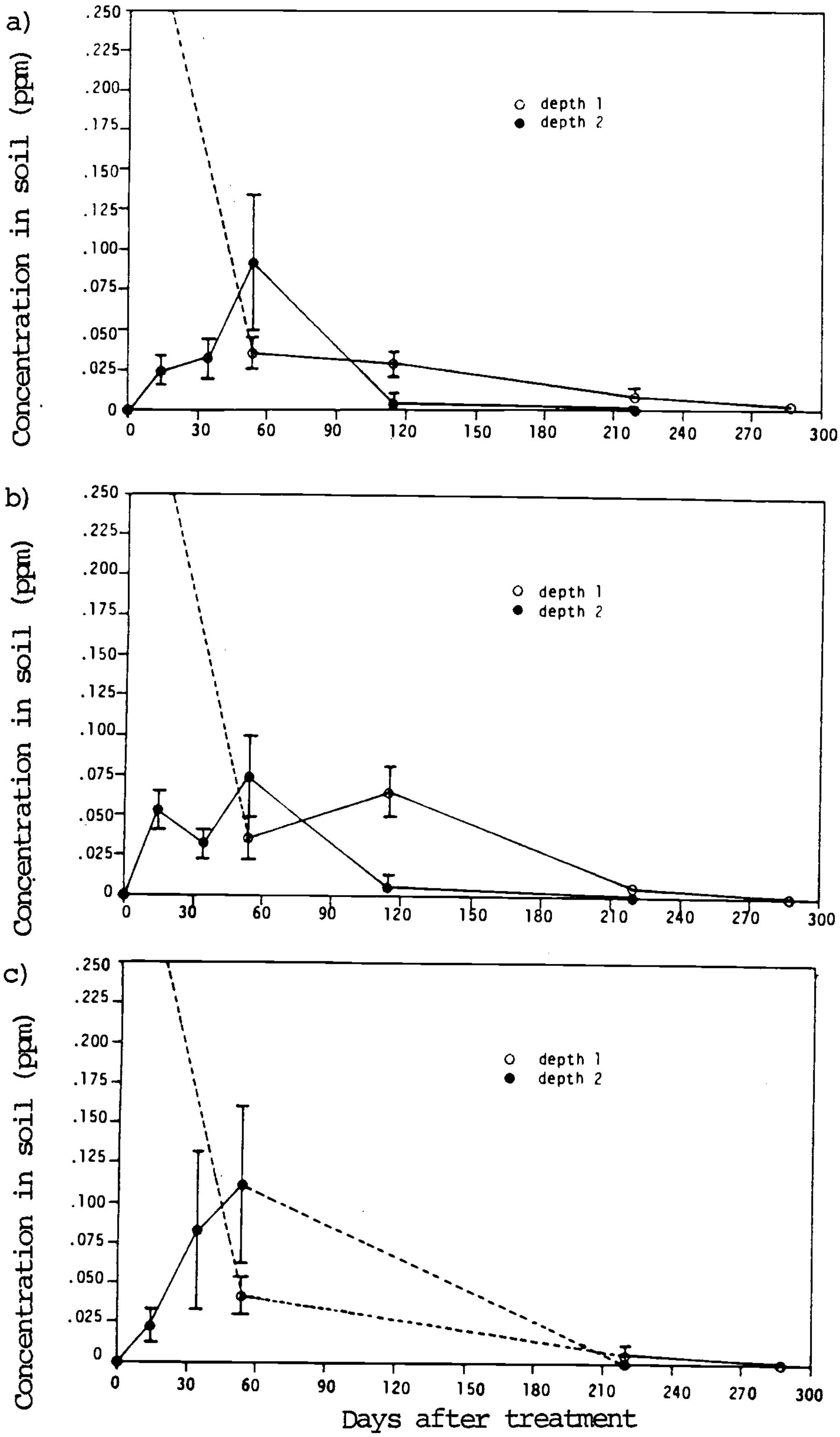


Figure 6. Clopyralid concentrations in soil at various sampling dates determined by visual symptoms of the indicator species growing in soil samples collected at different sampling dates after applying 0.56 kg/ha on September 12,1984. Vertical bars denote ± SE.
a) lentil, b) safflower, c) peas.

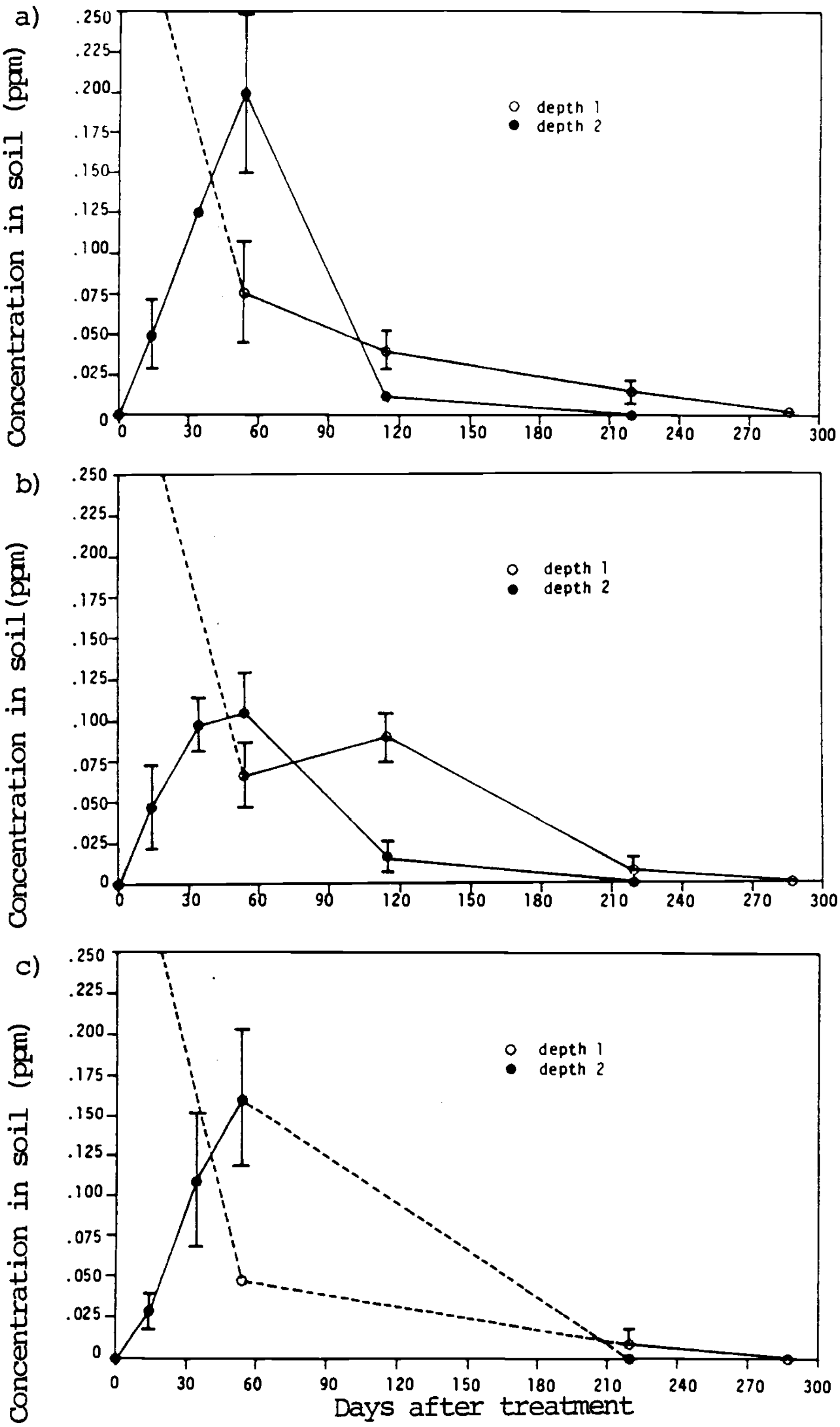


Figure 7. Clopyralid concentrations in soil determined by visual symptoms of the indicator species growing in soil samples collected at various sampling dates after applying 1.12 kg/ha on September 12,1984. Vertical bars denote standard error of the mean.
a) lentil, b) safflower, c) peas.

concentration was not high enough to produce symptoms on safflower or peas.

The faster degradation of clopyralid in the second depth can be partially explained by the warmer soil in this depth during the winter period which allowed more microorganism activity.

Standard errors shown in Figures 6 and 7. indicate more variation at higher clopyralid concentrations than at the low concentrations. Nonuniform distribution of the initial application of herbicide on soil may be responsible for much of the variation in the field. Fryer and Kirkland (1970) observed high variation in the initial recoveries of the applied rate of different herbicides after repeated treatments over 6 years. They also indicated that deposition of the spray application was another source of variation in field experiment.

Visible injury symptoms also were used as an indication of the presence of XRM-3785, as well as for clopyralid alone. The disappearance curves obtained by plotting the data from Appendix Table 16 are shown in Figures 8 and 9. No herbicide was detected in the second depth at 220 days for both rates of application. At 287 DAT, XRM-3785 was not detected in the first depth when applied at 0.56 kg/ha, but the amount remaining from the 1.12 kg/ha rate was sufficient to cause injury in all of the indicator plants. Although the injury was detected in all indicator plants, it was slight and temporary.

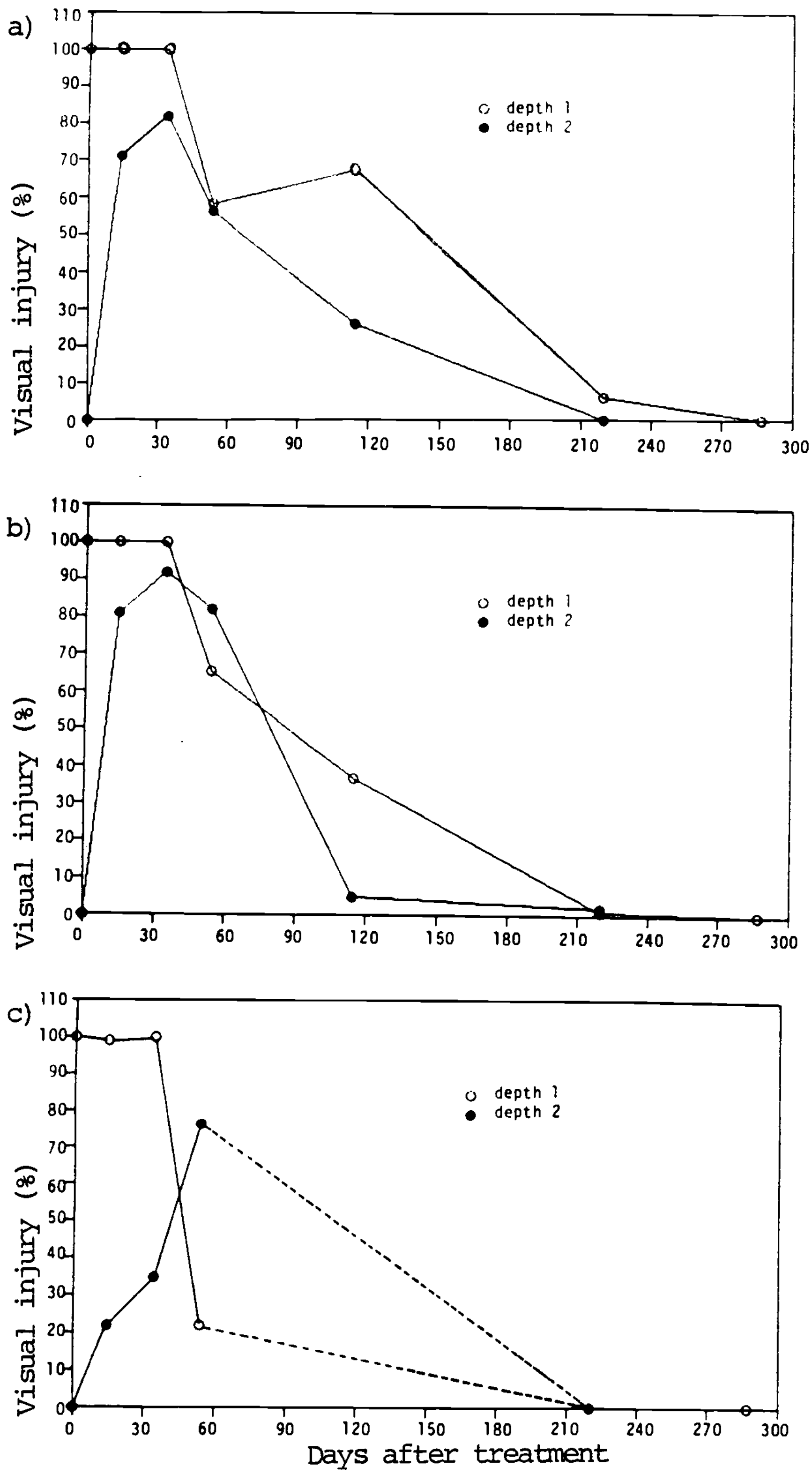


Figure 8. Visual injury of lentil (a), safflower (b), and peas (c) growing in soil samples collected from different depths at various sampling dates after applying XRM-3785 at 0.56 + 2.24 kg/ha on September 12,1984.

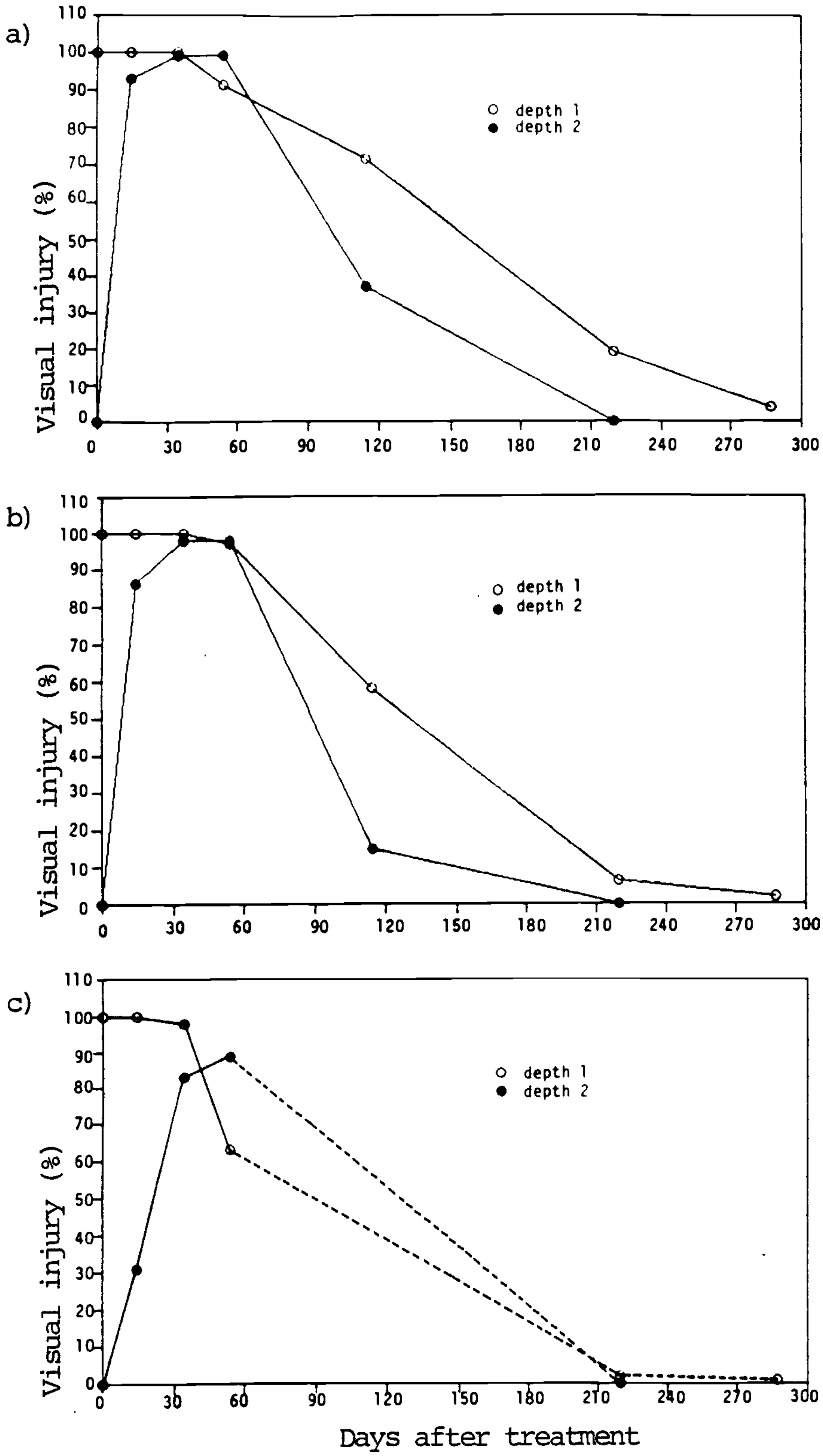


Figure 9. Visual injury of lentil (a), safflower (b), and peas (c) growing in soil samples collected from different depths at various sampling dates after applying XRM-3785 at 1.12 + 4.48 kg/ha on September 12,1984.

Many researchers have observed more sensitivity of plants to a herbicide in the greenhouse than in the field (14, 19, 24). Under field conditions the symptoms seen here may not show up. The slight symptoms may not affect crop yield. Fryer et al. (1977) observed no yield reduction in dwarf bean (Phaseolus vulgaris L.) growing in picloram-treated soil even though the injury symptoms persisted until harvest.

The herbicides in this experiment were sprayed on bare soil. In real situations when these herbicides are applied over a weed and crop canopy, persistence may be shorter. Moffat (1968) showed that a heavy growth of foliage can intercept 90% of the spray before it reaches the soil. The rates of clopyralid used for controlling some perennial weeds may be as high as 1.12 kg/ha. Under cold and dry conditions, this high rate may present persistence problems. To reduce the problem, spot treatment of these herbicides may be recommended.

When the disappearance patterns of clopyralid and XRM-3785 were compared, there was no indication that the addition of 2,4-D affected persistence. Clopyralid and XRM-3785 at the same amount of clopyralid disappeared from the soil at approximately the same time. These results are shown in Figures 10 and 11. Experiments should be conducted to study whether repeated application of these herbicides or related compounds will affect persistence.

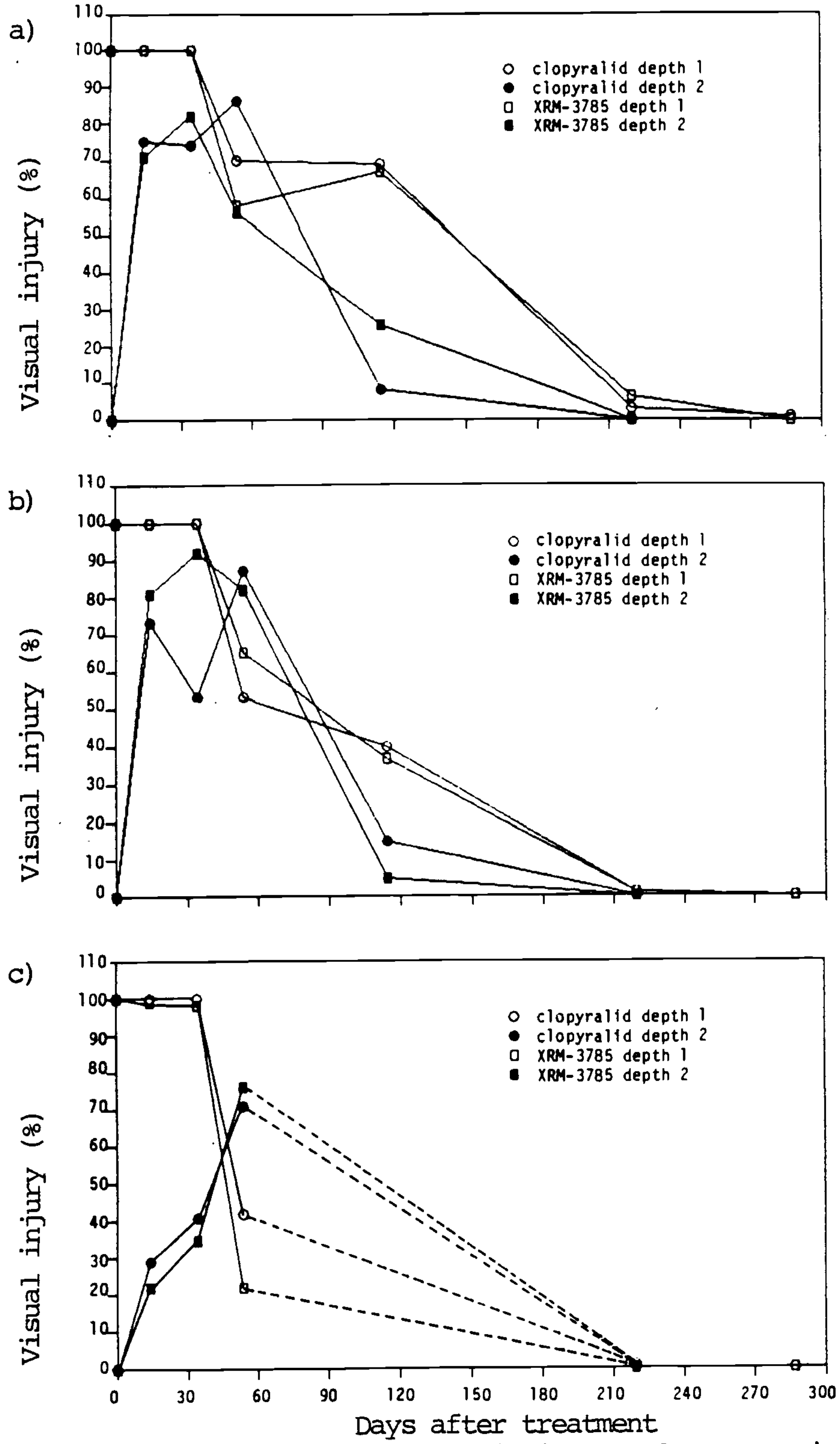


Figure 10. Visual injury of the indicator plants growing in soil samples collected from different depths at various sampling dates after applying clopyralid at 0.56 kg/ha and XRM-3785 at 0.56 + 2.24 kg/ha on September 12,1984. a) lentil, b) safflower, c) peas.

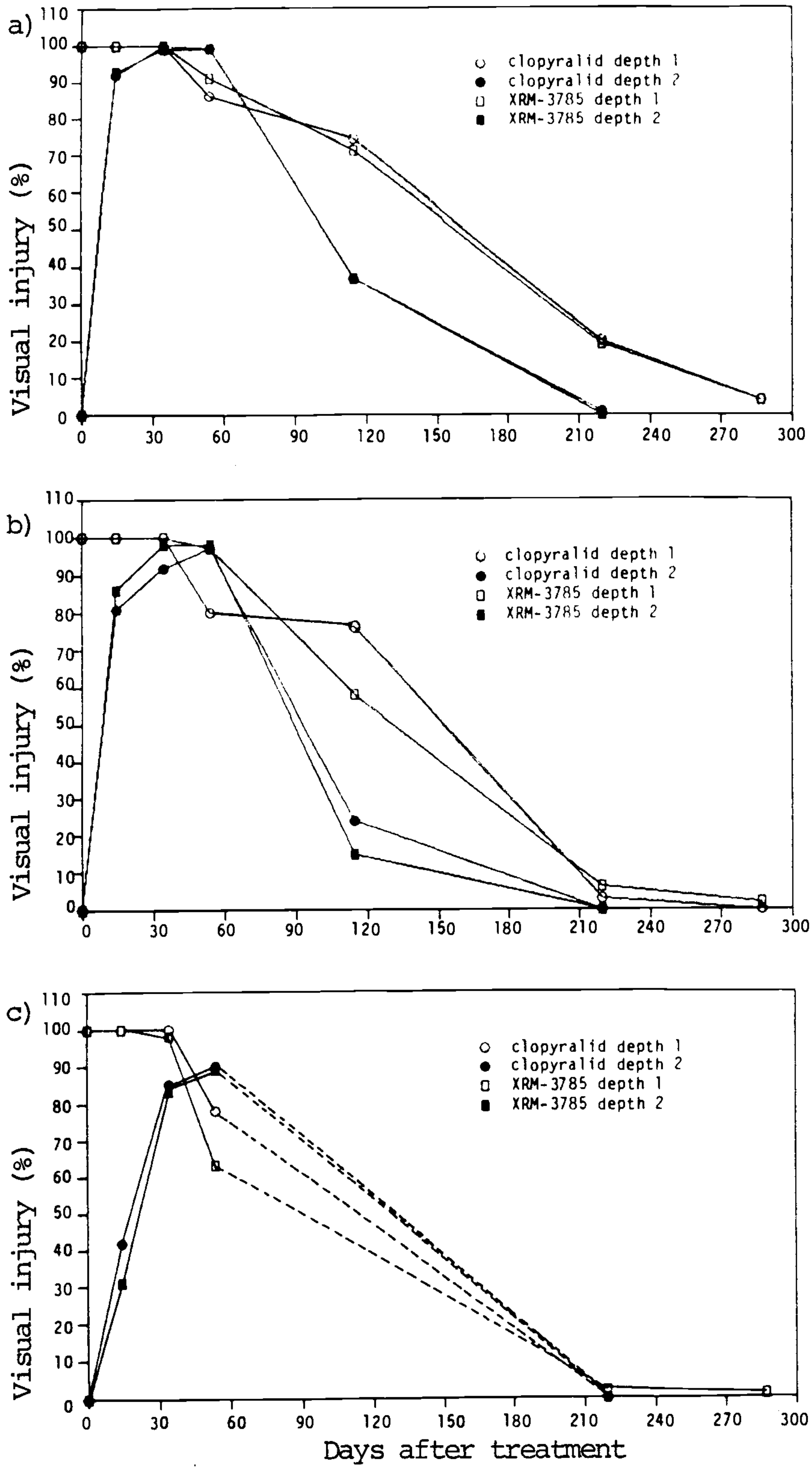


Figure 11. Visual injury of the indicator plants growing in soil samples collected from different depths at various sampling dates after applying clopyralid at 1.12 kg/ha and XRM-3785 at 1.12 + 4.48 kg/ha on September 12,1984. a) lentil, b) safflower, c) peas.

Spring Bioassay

At 56 DAT the amount of clopyralid and XRM-3785 remaining in the first depth killed lentils and safflower (Appendix Tables 25 to 28). Though some peas survived, severe injury was observed. Compared with the fall bioassay after the same elapsed time, more herbicide was detected in the first depth from the spring application. Precipitation during the 56 days after the spring application was 35 mm which was much less than that recorded for the same period after the fall application (224mm). The lower rainfall may be responsible for the slower disappearance of clopyralid from the first depth.

Herbicide injury was observed in the indicator species planted in soil collected from the second depth but it was not as severe as on the same sampling date of the fall bioassay. The injury was thought to be partly due to contamination during sampling. New methods of soil sampling should be developed so that contamination between depths is prevented. Most of clopyralid remained in the first depth under the lower rainfall, indicating that rainfall is an important factor in clopyralid disappearance from the soil. It may enhance herbicide dissipation through leaching and microbial degradation.

Supplementary assay

The results of the supplementary assay are presented in Table 5. Precipitation during the experiment was 803 mm. It appeared to be clopyralid residue that reduced the density of common groundsel in the treated plots. Clopyralid symptoms were seen in lentils in plots treated with 0.28 or 0.56 kg/ha. Herbicide injury was observed primarily on the young leaves. In some plants, stunting also was observed. The concentration was not high enough to cause symptoms on safflower or peas. These results are shown in Figure 12.

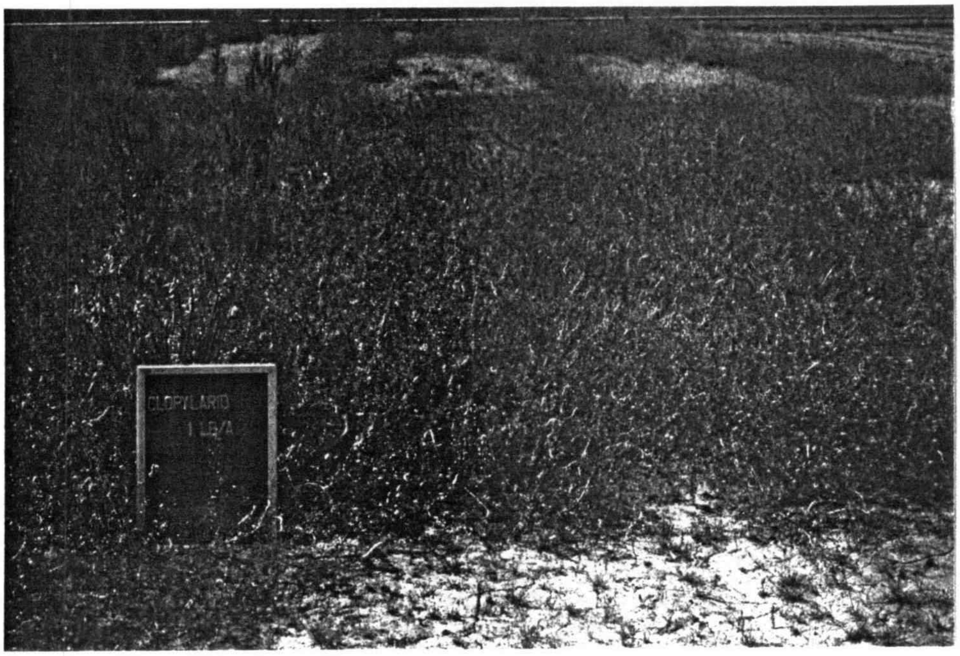
Table 5. Fresh weight and visual injury of the indicator plants growing in soil collected from North Lebanon, 208 days after clopyralid treatments.

Application rates	Fresh weight per plant (gm) R1	R2	R3	Visual injury (%) R1	R2	R3
Lentil						
Check	0.2925	0.0446	0.5979	0	0	0
0.14 kg/ha	0.4515	0.3904	0.3863	0	0	0
0.28 kg/ha	0.3155	0.1907	0.2625	30	25	15
0.56 kg/ha	0.3196	0.2576	0.3240	20	35	20
Safflower						
Check	0.2452	0.2631	0.6303	0	0	0
0.14 kg/ha	0.4303	0.3753	0.3147	0	0	0
0.28 kg/ha	0.2687	0.3170	0.2740	0	0	0
0.56 kg/ha	0.2573	0.2751	0.3304	0	0	0
Peas						
Check	2.0361	1.0759	2.1014	0	0	0
0.14 kg/ha	1.1643	1.6097	1.2425	0	0	0
0.28 kg/ha	1.8174	1.7746	1.7445	0	0	0
0.56 kg/ha	1.3711	1.7076	1.7359	0	0	0

Figure 12. Bioassay of soil samples collected from peppermint trial in North Lebanon, Oregon. The plots were treated with clopyralid at 0.56 kg/ha on September 26,1984. The assay was conducted at 208 DAT. Herbicide injury was observed on the young growing leaves of lentil. The pots in the back row are the check of each species.

This experiment showed that clopyralid was detectable in the soil 208 days after the application of 0.28 or 0.56 kg/ha in the fall. The amount remaining was high enough to prevent germination of some sensitive weeds, including common groundsel. In this case, the residue may be beneficial because it controls weeds during the winter period, when peppermint is dormant and not competitive. However, where crop rotation is a common practice, long persistence can limit the choice of the rotation crops. Careful decisions should be made before a highly sensitive crop is planted.

a)



b)

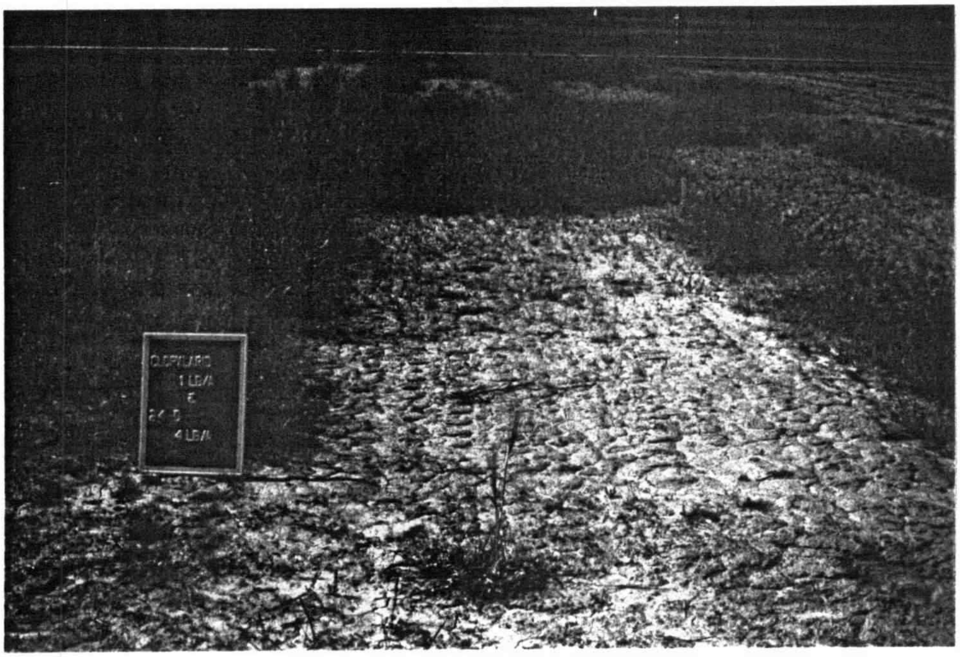


Figure 13. The pictures of the plots from the fall bioassay experiment. The plots were treated with a) clopyralid at 1.12 kg/ha and b) XRM-3785 at 1.12 + 4.48 kg/ha on September 12,1984. The pictures were taken in the summer of 1985.

CONCLUSION

Field experiments were conducted to determine the soil persistence of clopyralid under cropping situations. The results indicated that under Willamette Valley climatic conditions, clopyralid or XRM-3785 applied at a proposed use rate (0.14 kg/ha and 0.14 + 0.56 kg/ha, respectively) on wheat in spring and at a high rate (0.56 kg/ha and 0.56 + 2.24 kg/ha, respectively) on wheat stubble in summer would probably not result in herbicide residues harmful to wheat planted in the same fall or to a sensitive crop (safflower) planted in the next spring. But caution is advised. Greenhouse bioassays on soil treated with clopyralid and exposed to the same environment as the field studies showed that under certain conditions, injury to crops planted in the following spring is possible.

Greenhouse bioassays were conducted to determine the disappearance pattern of clopyralid and XRM-3785 from soil in the field. Clopyralid disappeared faster at the 10 to 20 cm depth than in the 0 to 10 cm depth. No herbicide was detected in the second depth 220 days after treatment. At 287 days after treatment, the amount remaining in the first depth from applications of 0.56 and 1.12 kg/ha was enough to produce slight symptoms on lentil, a plant highly sensitive to this herbicide.

If clopyralid was applied on August 1, the end of April would be about 270 days later and many spring-seeded crops are planted in April and May. Some comfort may be taken from the fact that plants grown in the greenhouse usually are more sensitive than those grown in the field but the warning is clear. There was no indication that the addition of 2,4-D affected persistence. Clopyralid and XRM-3785 at the same dosage of clopyralid disappeared from the soil at approximately the same time.

Clopyralid disappearance was slower in the spring than in the fall. Rainfall seems to be an important factor contributing to clopyralid disappearance from the soil. Under cold and dry conditions, active soil residues should be expected for longer periods than reported here.

The bioassay of soil samples collected from a peppermint trial treated with clopyralid at 0.56 kg/ha in the fall implied that the fewer common groundsel plants in the treated plots might have resulted from clopyralid activity in the soil. The residues might be sufficient to cause growth reduction in some sensitive weed species during the winter period. However, in the place where crop rotation is the normal practice, the residue may be harmful to the rotation crop.

Studies should be continued to determine whether these herbicides accumulate after many years of repeated application. Research also should be conducted to study the persistence of clopyralid under low rainfall condition and in different soil types.

LITERATURE CITED

1. Bovey, R. W. and H. S. Mayeux, Jr. 1980. Effectiveness and distribution of 2,4,5-T, triclopyr, picloram, and 3,6-dichloropicolinic acid in honey mesquite. Weed Sci. 28:666-670

2. Brown, J. G. and S. D. Uprichard. 1976. Control of problem weeds in cereals with 3,6-dichloropicolinic acid and mixtures with phenoxy herbicides. Proc. 1976 British Crop Protection Conference-Weeds, pp. 119-125.

3. Cseh, C. 1976. Residues of 3,6-dichloropicolinic acid, picloram, and dicamba in the soil. In Trabajos y Resumenes, III Congress Asociacion Latinoamericana de Malezas "ALAM" y, Mar del Plata, VIII Reunion Argentina de Malezas y su Control, "ASAM", Mar del Plata, Vol.1:21.

4. Devine, M. D. and W. H. Vanden Born. 1985. Absorption, translocation, and foliar activity of clopyralid and chlorsulfuron in Canada thistle and perennial sowthistle. Weed Sci. Vol.33:524-530.

5. Dow Chemical Co. 1974. Technical Information on DOWCO 290. Midland Mich.

6. Farrow, F. O. and H. H. Cheng. 1977. Degradation of 3,6-dichloropicolinic acid in the soil. Abstr. Weed. Sc. Soc. Am. p. 104.

7. Frans, R. E. and R. E. Talbert. 1977. Design of field experiments and the measurement and analysis of plant responses. In Research Methods in Weed Science 2nd Edition, (B. Truelove, Ed.). South. Weed Sci. Soc., U.S.A.

8. Fryer, J. D. and K. Kirkland. 1970. Field experiment to investigate long-term effects of repeated applications of MCPA, tri-allate, simazine, and linuron: report after 6 years. Weed Res. 10:133-158

9. Fryer, J. D., P. D. Smith, and J. W. Ludwig. 1979. Long-term persistence of picloram in a sandy loam soil. J. Environ. Qual., Vol. 8:83-85.

10. Grover, R. 1971. Adsorption of picloram by soil colloids and various other adsorbents. Weed Sci. 19:417-418.

11. Haagsma, T. 1975. DOWCO 290 herbicide--- A coming new selective herbicide. Down to Earth 30(4):1-2.

12. Hall, C. and W. H. Vanden Born. 1983. Translocation and metabolism of picloram and 3,6-dichloropicolinic acid in various plants. Abstr. Weed. Sc. Soc. Am. p. 83.

13. Hance, R. J., P. D. Smith, E. G. Cotterill and D.C. Reid. 1978. Herbicide persistence: effects of plant cover, previous history of the soil and cultivation. Med. Fac. Landbouww. Rijksuniv. Gent,43:1127-1134.

14. Horowitz, M. 1976. Application of bioassay techniques to herbicide investigations. Weed Res. Vol.16:209-215.

15. Horowitz, M. and G. Herzlinger. 1974. Soil conditions affecting dissipation of diuron, fluometuron and propham from the soil surface. Weed Res. 14:257-264.

16. Hurle, K. 1977. Biotest for detection of herbicides in the soil. In Crop Protection Agents, (N. R. McFarlane, Ed.). pp 285-306. Academic Press, London and New York.

17. Hurle, K. and A. Walker. 1980. Persistence and its prediction. Pages 83-122 in R. J. Hance (ed.). Interactions Between Herbicides and the Soil. Academic Press, London.

18. Keys, C. H. 1975. Evaluation of DOWCO 290 for the control of annual and perennial weeds. Down to Earth 31(1):1-7.

19. Lynch, M. R. and R. B. Sweet. 1971. Effect of environment on activity of diphenamid. Weed Sci. Vol.19:332-337

20. Merkle, M.G., R.W. Bovey, and R. Hall. 1966. The determination of picloram residues in soil using gas chromatography. Weeds 14:161-164.

21. Miller, S. D. and H. P. Alley. 1985. Broadleaf weed control in small grain with DOWCO 290. Abstr. Weed. Sc. Soc. Am. p. 9.

22. Moffat, R. W. 1968. Some factors affecting the disappearance of TORDON in soil. Down to Earth 23(4):6-10.

23. Naish, R. W. 1975. DOWCO 290--- A new growth regulator herbicide. Proc. 28th N.Z. Weed and Pest Control Conf.:177-180

24. Olson, D. L. 1975. The soil persistence and crop selectivity of 3,6-dichloropicolinic acid. M.S. Thesis, Oregon State University, Corvallis.

25. O'Sullivan, P. A. and K. J. Kirkland. 1984. Control of Avena fatua L. and Cirsium arvense (L.) Scop. with mixtures of 3,6-dichloropicolinic acid and four herbicides for control of Avena fatua. Weed Res. 24:23-28.

26. O'Sullivan, P.A. and V. C. Kossatz. 1982. Selective control of Canada thistle in rapeseed with 3,6-dichloropicolinic acid. Can. J. Plant Sci. 62:989-993.

27. O'Sullivan, P. A. and V. C. Kossatz. 1984. Absorption and translocation of 14C-3,6-dichloropicolinic acid in Cirsium arvense (L.) Scop. Weed Res. 24:17-22.

28. Pik, A. J., E. Peake, M. T. Strosher, and G. W. Hodgson. 1977. Fate of 3,6-dichloropicolinic acid in soils. J. Agric. Food Chem. Vol. 25(5):1054-1061.

29. Santelmann, P. W. 1977. Herbicide Bioassay. In B. Truelove (ed.), Research Methods in Weed Science 2nd Edition. South. Weed Sci. Soc., U.S.A.

30. Turnbull, G. L. and G. R. Stephenson. 1985. Translocation of clopyralid and 2,4-D in Canada thistle (Cirsium arvense). Weed Sci. 33:143-147.

31. Vanden Born, W. H. and R. J. Schraa. 1975. Control of 2,4-D resistant weeds in small grains with DOWCO 290 herbicide. Down to Earth. Vol. 31:4-9.

32. Weed Science Society of America. 1983. Herbicide Handbook Fifth Edition. Champaign, Ill. 515 pp.

33. Whiteside, R. E. and A. P. Appleby. 1979. DOWCO 290 herbicide for selective control of Canada thistle in peppermint. Down to Earth, Vol.35:14-18.

34. Youngson, C. R., C. A. I. Goring, R. W. Meikel, H. H. Scott, and J. D. Griffith. 1967. Factors influencing the decomposition of TORDON herbicides in soil. Down to Earth 23(2):3-11.

APPENDICES

Appendix Table 1. Winter Wheat Grain yield (kg) taken on July 23,1985 following the applications of clopyralid, XRM-3785, and 2,4-D, each applied at proposed use rate on May 17,1984 and at high rate on August 15,1984.

Treatment	Replication				
	I	II	III	IV	Average
1. Clopyralid 0.14 kg/ha 0.28 kg/ha	11.0	10.9	11.9	9.4	10.8
2. Clopyralid 0.14 kg/ha 0.56 kg/ha	8.9	13.4	14.4	8.2	11.2
3. XRM-3785 0.14+0.56 kg/ha 0.56+2.24 kg/ha	10.8	10.7	15.6	11.8	12.2
4. 2,4-D 0.56 kg/ha 2.24 kg/ha	8.4	11.4	12.0	13.6	11.4
5. Check	11.7	9.1	10.9	11.2	10.7

Appendix Table 2. Analysis of variance for data in Appendix Table 1.

Source	DF	SS	MS	F
Replication	3	21.51	7.17	
Treatment	4	5.76	1.44	.384 ns
Error	12	45.00	3.75	
Total	19	72.27		

C.V. = 17%

Appendix Table 3. Effect of herbicide residue on winter Wheat Yield (MT/ha) in supplementary Trial.

Treatment	Rate (kg/ha)	Replication I	II	III	IV	V	Average
Clopyralid	0.28	10.8	11.9	11.3	10.2	9.8	10.8
Clopyralid	0.56	10.9	11.0	11.8	11.2	11.3	11.2
Clopyralid	1.12	11.8	11.0	9.9	10.4	11.1	10.8
XRM-3785	0.56	11.6	12.2	11.5	11.3	11.0	11.5
2,4-D	2.24	11.3	11.9	11.1	10.3	11.3	11.2
Check	-	10.8	12.2	10.5	11.4	12.0	11.4

Appendix Table 4. Analysis of variance for data in Appendix Table 3.

Source	DF	SS	MS	F
Replication	4	575.12	143.78	
Treatment	5	468.75	93.75	1.22 ns
Error	20	1542.20	77.11	
Total	29	2586.07		

C.V. = 5.3 %

Appendix Table 5. Safflower fresh weight (kg) taken on August 1,1985 following the applications of clopyralid,XRM-3785,and 2,4-D, each applied at proposed use rate on May 17,1984 and at high rate on August 15,1984

Treatment	Replication				
	I	II	III	IV	Average
1. Clopyralid 0.14 kg/ha 0.28 kg/ha	19.6	24.4	22.2	18.1	21.1
2. Clopyralid 0.14 kg/ha 0.56 kg/ha	15.5	19.6	21.0	15.2	17.8
3. XRM-3785 0.14+0.56 kg/ha 0.56+2.24 kg/ha	20.1	19.0	19.0	17.1	19.6
4. 2,4-D 0.56 kg/ha 2.24 kg/ha	22.0	20.7	19.1	20.1	20.5
5. Check	16.7	22.0	20.8	18.0	19.4

Appendix Table 6. Analysis of Variance for data in Appendix Table 5.

Source	DF	SS	MS	F
Replication	3	233.34	77.78	
Treatment	4	120.16	30.04	2.03 ns
Error	12	177.60	14.80	
Total	19	531.10		

C.V. = 8.9%

Appendix Table 7. Shoot fresh weight and visual injury of the indicator species growing in soil treated with various concentrations of clopyralid at 14 DAT (fall).

clopyralid ppm dry soil	Fresh weight per plant(g) R1	R2	Avg	POC(%)[a]	Visual injury (%) R1	R2	Avg
Lentil							
0.0039	0.3369	0.3629	0.3499	102	0	0	0
0.0078	0.3390	0.2689	0.3039	89	0	20	10
0.0156	0.1241	0.1314	0.1277	37	60	60	60
0.0313	0.0306	0.0226	0.0266	8	80	90	85
0.0625	0.0000	0.0119	0.0059	2	100	95	98
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.3251	0.3603	0.3427	100	0	0	0
Safflower							
0.0039	0.5924	0.6205	0.6064	98	10	10	10
0.0078	0.5823	0.8469	0.7146	117	10	10	10
0.0156	0.4796	0.6868	0.5832	95	50	50	50
0.0313	0.6058	0.4065	0.5061	81	60	60	60
0.0625	0.0823	0.1667	0.1245	21	90	70	80
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.6545	0.5856	0.6201	100	0	0	0
Peas							
0.0039	1.0816	0.7151	0.8983	122	0	0	0
0.0078	0.5213	0.9597	0.7405	109	5	0	3
0.0156	0.6646	0.9495	0.8070	117	10	10	10
0.0313	0.4790	0.1409	0.3099	40	60	80	70
0.0625	0.1459	0.3469	0.2464	37	70	70	70
0.1250	0.1783	0.0000	0.0892	10	90	100	95
0.2500	0.0000	0.0747	0.0374	6	100	90	95
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.8549	0.6095	0.7322	100	0	0	0

a Percent of check.

Appendix Table 8. Shoot fresh weight and visual injury of the indicator species growing in soil treated with various concentrations of clopyralid at 34 DAT.

clopyralid	Fresh weight per plant(g)				Visual injury (%)		
ppm dry soil	R1	R2	Avg	POC(%)	R1	R2	Avg
Lentil							
0.0039	0.3805	0.2881	0.3343	108	0	20	10
0.0078	0.2201	0.2013	0.2107	68	30	50	40
0.0156	0.1605	0.0899	0.1252	41	50	60	55
0.0313	0.0385	0.0363	0.0374	12	70	80	75
0.0625	0.0267	0.0261	0.0264	9	95	90	93
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.3012	0.3191	0.3101	100	0	0	0
Safflower							
0.0039	0.5362	0.5213	0.5287	97	5	5	5
0.0078	0.5833	0.4169	0.5001	91	10	20	15
0.0156	0.5378	0.3970	0.4674	85	40	50	45
0.0313	0.4208	0.4620	0.4414	81	60	60	60
0.0625	0.2194	0.0730	0.1462	26	70	90	80
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.5648	0.5272	0.5460	100	0	0	0
Peas							
0.0039	0.5145	0.5203	0.5174	104	0	0	0
0.0078	0.5098	0.2360	0.3729	79	5	5	5
0.0156	0.1510	0.1209	0.1359	28	20	10	15
0.0313	0.2501	0.3195	0.2848	56	40	30	35
0.0625	0.1117	0.1665	0.1391	27	70	70	70
0.1250	0.1245	0.0000	0.0623	14	90	100	95
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.4297	0.5932	0.5115	100	0	0	0

Appendix Table 9. Shoot fresh weight and visual injury of the indicator species growing in soil treated with various concentrations of clopyralid at 54 DAT.

clopyralid ppm dry soil	Fresh-weight per plant(g) R1	R2	Avg	POC(%)	Visual injury (%) R1	R2	Avg
Lentil							
0.0039	0.2353	0.2936	0.2644	94	10	10	10
0.0078	0.1991	0.1981	0.1986	71	20	20	20
0.0156	0.1117	0.1187	0.1152	41	60	60	60
0.0313	0.0203	0.0900	0.0551	19	80	70	75
0.0625	0.0173	0.0227	0.0200	7	90	90	90
0.1250	0.0550	0.0000	0.0275	10	90	100	95
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.2744	0.2894	0.2819	100	0	0	0
Safflower							
0.0039	0.4750	0.5266	0.5008	100	0	10	5
0.0078	0.4087	0.5113	0.4600	92	30	30	30
0.0156	0.4243	0.4379	0.4311	86	50	40	45
0.0313	0.0000	0.4544	0.2272	47	100	60	80
0.0625	0.2290	0.0380	0.1335	26	70	80	75
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.5225	0.4830	0.5027	100	0	0	0
Peas							
0.0039	0.4672	0.4821	0.4746	92	0	0	0
0.0078	0.7605	0.2300	0.4953	100	0	60	30
0.0156	0.1213	0.5995	0.3604	66	40	30	35
0.0313	0.3727	0.0544	0.2135	44	20	90	55
0.0625	0.0000	0.0797	0.0399	7	100	70	85
0.1250	0.2347	0.1539	0.1943	38	60	80	70
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.4783	0.5618	0.5201	100	0	0	0

Appendix Table 10. Shoot fresh weight and percent injury of the indicator species growing in soil treated with various concentrations of clopyralid at 114 DAT.

clopyralid	Fresh weight per plant(g)				Visual injury (%)		
ppm dry soil	R1	R2	Avg	POC(%)	R1	R2	Avg
Lentil							
0.0039	0.3113	0.3414	0.3263	93	10	10	10
0.0078	0.3069	0.3561	0.3315	95	30	30	30
0.0156	0.3478	0.3205	0.3342	95	40	40	40
0.0313	0.1818	0.1865	0.1842	52	70	80	75
0.0625	0.0790	0.0211	0.0501	14	80	80	80
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.3694	0.3354	0.3524	100	0	0	0
Safflower							
0.0039	0.5951	0.4331	0.5141	120	0	0	0
0.0078	0.4860	0.4759	0.4810	112	0	0	0
0.0156	0.4526	0.4673	0.4599	107	20	25	23
0.0313	0.5481	0.5594	0.5537	129	30	40	35
0.0625	0.5172	0.5252	0.5212	121	50	50	50
0.1250	0.3808	0.0538	0.2173	51	70	90	80
0.2500	0.0000	0.2835	0.1418	32	100	80	90
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.4221	0.4376	0.4299	100	0	0	0

Appendix Table 11. Shoot fresh weight and visual injury of the indicator species growing in soil treated with various concentrations of clopyralid at 220 DAT.

clopyralid	Fresh weight per plant(g)				Visual injury (%)		
ppm dry soil	R1	R2	Avg	POC(%)	R1	R2	Avg
Lentil							
0.0039	0.7125	0.6899	0.7012	109	0	0	0
0.0078	0.6716	0.5277	0.5996	94	0	10	5
0.0156	0.4345	0.4977	0.4661	72	30	20	25
0.0313	0.1742	0.2890	0.2316	35	60	60	60
0.0625	0.0000	0.0000	0.0000	0	100	100	100
0.1250	0.0000	0.0000	0.0000	0	100	100	100
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.6122	0.6813	0.6467	100	0	0	0
Safflower							
0.0039	0.6019	0.6393	0.6206	92	10	10	10
0.0078	0.6971	0.6080	0.6526	97	20	20	20
0.0156	0.8180	0.7300	0.7740	114	40	40	40
0.0313	0.6533	0.5023	0.5778	86	60	60	60
0.0625	0.5144	0.3769	0.4456	66	70	70	70
0.1250	0.0000	0.2532	0.1266	18	100	80	90
0.2500	0.0000	0.1510	0.0755	11	100	90	95
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	0.6566	0.6995	0.6780	100	0	0	0
Peas							
0.0039	1.9064	1.4180	1.6622	96	0	0	0
0.0078	1.6365	1.3082	1.4723	85	0	0	0
0.0156	1.1451	1.5493	1.3472	75	10	0	5
0.0313	1.7535	0.9451	1.3493	79	30	30	30
0.0625	0.9092	0.1897	0.5494	33	60	80	70
0.1250	0.4220	0.2564	0.3392	20	70	70	70
0.2500	0.0000	0.0000	0.0000	0	100	100	100
0.5000	0.0000	0.0000	0.0000	0	100	100	100
0.0000	1.5929	1.9714	1.7822	100	0	0	0

Appendix Table 12. Shoot fresh weight of the indicator species growing in soil treated with various concentrations of clopyralid at 287 DAT.

clopyralid ppm dry soil	Fresh-weight per plant (g) R1	R2	Avg	POC(%)
Lentil				
0.0039	0.4161	0.6507	0.5334	118
0.0078	0.4757	0.2207	0.3482	93
0.0156	0.1974	0.0000	0.0987	31
0.0313	0.0000	0.0000	0.0000	0
0.0625	0.0000	0.0000	0.0000	0
0.1250	0.0000	0.0000	0.0000	0
0.2500	0.0000	0.0000	0.0000	0
0.5000	0.0000	0.0000	0.0000	0
0.0000	0.3146	0.6220	0.4683	100
Safflower				
0.0039	0.7896	1.0578	0.9237	120
0.0078	0.8633	1.0105	0.9369	122
0.0156	1.1309	0.8424	0.9867	131
0.0313	0.0000	0.4581	0.2290	28
0.0625	0.0000	0.0000	0.0000	0
0.1250	0.0000	0.0000	0.0000	0
0.2500	0.0000	0.0000	0.0000	0
0.5000	0.0000	0.0000	0.0000	0
0.0000	0.7126	0.8201	0.7664	100
Peas				
0.0039	2.0676	2.2801	2.1738	100
0.0078	1.9528	2.0560	2.0044	92
0.0156	1.8551	1.6932	1.7742	82
0.0313	1.6880	1.5023	1.5952	74
0.0625	1.6359	1.4138	1.5249	71
0.1250	0.2028	0.2207	0.2117	10
0.2500	0.0000	0.0810	0.0405	2
0.5000	0.0000	0.0811	0.0406	2
0.0000	2.0815	2.2601	2.1708	100

Appendix Table 13. Estimated clopyralid concentrations (ppm) in soil at several dates following the September 12, 1984 application of 0.56 kg/ha. Estimates made by comparing symptoms with those on the same species growing in known concentrations. Values are means of four replications from Appendix Table 29.

DAT	Depth (cm)	Lentil	Safflower	Peas
0	0-10	0.375 ±0.000	0.375 ±0.000	0.375 ±0.000
	10-20	0.000 ±0.000	0.000 ±0.000	0.000 ±0.000
14	0-10	>.125	>.125	>.250
	10-20	0.024 ±0.008	0.053 ±0.015	0.022 ±0.002
34	0-10	>.125	>.125	>.250
	10-20	0.032 ±0.009	0.032 ±0.009	0.083 ±0.056
54	0-10	0.035 ±0.007	0.035 ±0.007	0.041 ±0.006
	10-20	0.092 ±0.053	0.074 ±0.029	0.112 ±0.050
114	0-10	0.029 ±0.006	0.065 ±0.018	-
	10-20	0.004 ±0.001	0.005 ±0.003	-
220	0-10	0.008 ±0.002	0.006 ±0.000	0.005 ±0.001
	10-20	0.000 ±0.000	0.000 ±0.000	0.000 ±0.000
287	0-10	0.002 ±0.000	0.000 ±0.000	0.000 ±0.000
	10-20	-	-	-

Appendix Table 14. Estimated clopyralid concentrations (ppm) in soil at several dates following the September 12, 1984 application of 1.12 kg/ha. Estimates made by comparing symptoms with those on the same species growing in known concentrations. Values are means of four replications from Appendix Table 30.

DAT	Depth (cm)	Lentil	Safflower	Peas
0	0-10	0.750 ±0.000	0.750 ±0.000	0.750 ±0.000
	10-20	0.000 ±0.000	0.000 ±0.000	0.000 ±0.000
14	0-10	>.125	>.125	>.250
	10-20	0.049 ±0.025	0.047 ±0.017	0.029 ±0.006
34	0-10	>.125	>.125	>.250
	10-20	0.125 ±0.000	0.098 ±0.018	0.109 ±0.048
54	0-10	0.076 ±0.038	0.066 ±0.020	0.047 ±0.000
	10-20	0.199 ±0.162	0.105 ±0.020	0.160 ±0.053
114	0-10	0.040 ±0.006	0.090 ±0.016	- -
	10-20	0.012 ±0.000	0.016 ±0.004	- -
220	0-10	0.015 ±0.003	0.007 ±0.005	0.009 ±0.003
	10-20	0.000 ±0.000	0.000 ±0.000	0.000 ±0.000
287	0-10	0.002 ±0.000	0.000 ±0.000	0.000 ±0.000
	10-20	-	-	-

Appendix Table 15. Analysis of variance of fresh weights of three indicator species growing in soil collected from 0 to 10 cm depth at 220 DAT (greenhouse bioassay experiment).

a. lentil

Source	DF	SS	MS	F
Replication	3	0.030	0.010	0.775
Treatment	5	0.093	0.019	1.440 ns
Error	15	0.194	0.013	
Total	23	0.317		

C.V. = 24%

b. safflower

Source	DF	SS	MS	F
Replication	3	0.011	0.004	0.493
Treatment	5	0.071	0.014	1.890 ns
Error	15	0.113	0.008	
Total	23	0.195		

C.V. = 17%

c. peas

Source	DF	SS	MS	F
Replication	3	0.190	0.063	0.303
Treatment	5	0.520	0.104	0.510 ns
Error	15	3.12	0.208	
Total	23	3.83		

C.V. = 38%

Appendix Table 16. Visual injury of indicator plants growing in soil different sampling dates following the application of XRM-3785 at 0.56 kg/ha and 1.12 kg/ha on September,12,1984. The values are the average of four replications.

		Rates (kg/ha)					
DAT	Depth	Lentil		Safflower		Peas	
	(cm)	0.56	1.12	0.56	1.12	0.56	1.12
0	0-10	100	100	100	100	100	100
	10-20	0	0	0	0	0	0
14	0-10	100	100	100	100	99	100
	10-20	71	93	81	86	22	31
34	0-10	100	100	100	100	100	98
	10-20	82	99	92	98	35	83
54	0-10	58	91	65	97	22	63
	10-20	56	99	82	98	76	89
114	0-10	67	71	37	58	-	-
	10-20	26	37	5	15	-	-
220	0-10	6	19	1	6	0	2
	10-20	0	0	2	0	0	0
287	0-10	0	4	0	2	0	1
	10-20	-	-	-	-	-	-

Appendix Table 17. Visual injury of indicator plants growing in soil different sampling dates following the application of clopyralid (clo.) and XRM-3785 (xrm.) at 0.56 kg/ha on September,12,1984. The values are the average of four replications

DAT	Depth	Lentil		Safflower		Peas	
	(cm)	clo.	xrm.	clo.	xrm.	clo.	xrm.
0	0-10	100	100	100	100	100	100
	10-20	0	0	0	0	0	0
14	0-10	100	100	100	100	100	99
	10-20	75	71	73	81	29	22
34	0-10	100	100	100	100	100	98
	10-20	74	82	53	92	41	35
54	0-10	70	58	53	65	42	22
	10-20	86	56	87	82	71	76
114	0-10	69	67	40	37	-	-
	10-20	8	26	15	5	-	-
220	0-10	3	6	1	1	1	0
	10-20	0	0	0	0	0	0
287	0-10	1	0	0	0	0	0
	10-20	-	-	-	-	-	-

Appendix Table 18. Visual injury of indicator plants at various soil sampling dates following the applications of clopyralid (clo.) and XRM-3785 (xrm.) at 1.12 kg/ha on September,12,1984.

DAT	Depth (cm)	Lentil		Safflower		Peas	
		clo.	xrm.	clo.	xrm.	clo.	xrm.
0	0-10	100	100	100	100	100	100
	10-20	0	0	0	0	0	0
14	0-10	100	100	100	100	100	100
	10-20	92	93	81	86	42	31
34	0-10	100	100	100	100	100	98
	10-20	100	99	92	98	85	83
54	0-10	86	91	80	97	78	63
	10-20	99	99	97	98	90	89
114	0-10	74	71	76	58	-	-
	10-20	37	37	24	15	-	-
220	0-10	20	19	3	6	0	2
	10-20	1	0	0	0	0	0
287	0-10	4	4	0	2	0	1
	10-20	-	-	-	-	-	-

Appendix Table 19. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 14 days after the applications of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Species	Fresh weight per plant (g)					POC(%)	Visual injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.0000	0.0000	0.0448	0.0112	5	100	100	100	80	95
T6	0.3055	0.3301	0.2754	0.2456	0.2890	100	0	0	0	0	0
Avg	0.0509	0.0550	0.0459	0.0484	0.0500						
Safflower											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.0000	0.1406	0.2243	0.0912	28	100	100	90	70	90
T6	0.5680	0.5650	0.3462	0.3146	0.4485	100	0	0	0	0	0
Avg	0.0947	0.0942	0.0811	0.0898	0.0900						
Peas											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0783	0.0000	0.0000	0.0000	0.0196	3	95	100	100	100	99
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.0000	0.0000	0.3625	0.0906	14	100	100	100	70	93
T6	0.7212	0.6302	0.6490	0.6563	0.6642	100	0	0	0	0	0
Avg	0.1333	0.1050	0.1082	0.1698	0.1291						

Appendix Table 19. (continue).

Treatment	Fresh weight per plant (g)					POC (%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.0414	0.1271	0.0330	0.1415	0.0858	32	80	70	85	60	74
T2	0.0000	0.0359	0.0570	0.0365	0.0324	11	100	90	85	80	89
T3	0.1414	0.0443	0.1266	0.1076	0.1050	35	60	90	60	70	70
T4	0.0000	0.0512	0.0337	0.0710	0.0390	15	100	90	80	90	90
T5	0.1909	0.2644	0.2202	0.1475	0.2058	68	10	0	10	0	5
T6	0.3459	0.2906	0.3618	0.2221	0.3051	100	0	0	0	0	0
Avg	0.1199	0.1356	0.1387	0.1210	0.1288						
Safflower											
T1	0.3126	0.0955	0.4383	0.5352	0.3454	70	70	95	70	50	71
T2	0.0000	0.3474	0.2567	0.6170	0.3053	61	100	60	80	60	75
T3	0.0961	0.3243	0.3713	0.1420	0.2334	46	90	80	60	90	80
T4	0.0000	0.2009	0.3553	0.2302	0.1966	39	100	85	70	70	81
T5	0.2089	0.4638	0.3606	0.2348	0.3170	64	80	10	50	70	53
T6	0.4687	0.4988	0.5213	0.4963	0.4963	100	0	0	0	0	0
Avg	0.1811	0.3218	0.3839	0.3759	0.3157						
Peas											
T1	0.5500	0.5123	0.5939	0.6157	0.5680	88	50	30	30	10	30
T2	0.4044	0.4351	0.4052	0.4706	0.4288	67	70	40	40	20	43
T3	0.5543	0.4929	0.5486	0.4097	0.5014	78	20	30	20	20	23
T4	0.3706	0.7016	0.3389	0.6343	0.5114	82	60	20	40	10	33
T5	0.3880	0.4288	0.7102	0.2930	0.4550	77	10	30	0	40	20
T6	0.8068	0.5414	0.6219	0.6519	0.6555	100	0	0	0	0	0
Avg	0.5124	0.5187	0.5365	0.5125	0.5200						

Appendix Table 20. Fresh weight and visual injury of the indicator species planted in soil samples collected at 34 days after the applications of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0999	0.0927	0.0898	0.1424	0.1062	33	40	50	70	40	50
T6	0.2873	0.3416	0.3269	0.3400	0.3240	100	0	0	0	0	0
Avg	0.0645	0.0724	0.0695	0.0804	0.0717						
Safflower											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.2590	0.2133	0.2354	0.1867	0.2236	78	70	50	50	40	53
T6	0.3424	0.3757	0.2165	0.2710	0.3014	100	0	0	0	0	0
Avg	0.1002	0.0982	0.0753	0.0763	0.0875						
Peas											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0875	0.0000	0.1270	0.0536	7	100	100	100	70	93
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.3775	0.3112	0.2406	0.2323	42	100	30	30	40	53
T6	0.3927	0.6391	0.5202	0.4780	0.5075	100	0	0	0	0	0
Avg	0.0655	0.1840	0.1386	0.1409	0.1322						

Appendix Table 20. (continue).

Treatment	Fresh weight per plant (g)					POC(%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.0069	0.1868	0.1362	0.0145	0.0861	29	95	50	60	80	71
T2	0.0000	0.0093	0.0000	0.0000	0.0023	1	100	100	100	100	100
T3	0.0538	0.0000	0.0390	0.0685	0.0403	21	70	100	70	70	78
T4	0.0000	0.0000	0.0000	0.0351	0.0088	3	100	100	100	90	98
T5	0.3113	0.2890	0.2983	0.3241	0.3057	143	0	0	0	0	0
T6	0.1139	0.3170	0.2979	0.2965	0.2563	100	0	0	0	0	0
Avg	0.0810	0.1337	0.1286	0.1231	0.1166						
Safflower											
T1	0.2844	0.5010	0.4448	0.2765	0.3767	107	70	40	30	70	53
T2	0.0912	0.3041	0.0000	0.0000	0.0988	24	80	60	100	100	85
T3	0.2340	0.0000	0.2149	0.0000	0.1122	31	70	100	70	100	85
T4	0.0000	0.0000	0.0000	0.2740	0.0685	26	100	100	100	70	93
T5	0.1899	0.4873	0.3784	0.3495	0.3512	102	10	0	0	0	3
T6	0.3946	0.4200	0.3374	0.2662	0.3546	100	0	0	0	0	0
Avg	0.1990	0.2854	0.2293	0.1944	0.2270						
Peas											
T1	0.0000	0.4580	0.5842	0.4892	0.3829	64	100	10	5	40	39
T2	0.1241	0.2463	0.0000	0.0550	0.1064	17	70	70	100	80	80
T3	0.5858	0.3505	0.2855	0.2632	0.3713	64	20	50	40	30	35
T4	0.0000	0.0207	0.3211	0.3164	0.1646	29	100	95	50	60	76
T5	0.4829	0.4403	0.2308	0.7406	0.4737	77	0	20	30	0	13
T6	0.5366	0.6876	0.4888	0.7052	0.6046	100	0	0	0	0	0
Avg	0.2880	0.3672	0.3184	0.4283	0.3505						

Appendix Table 21. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 54 days after the applications of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Treatment	Fresh weight per plant (g)					POC(%)	Visual injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0825	0.0496	0.0336	0.0483	0.0535	21	60	70	80	70	70
T2	0.0320	0.0095	0.0485	0.0190	0.0273	10	90	90	70	90	85
T3	0.0235	0.2630	0.0348	0.1756	0.1242	53	80	30	70	50	58
T4	0.1531	0.0000	0.0000	0.0523	0.0514	21	50	100	100	80	83
T5	0.3241	0.2908	0.2620	0.2391	0.2790	107	0	10	0	0	3
T6	0.3215	0.3466	0.3334	0.1463	0.2870	100	0	0	0	0	0
Avg	0.1561	0.1599	0.1187	0.1134	0.1370						
Safflower											
T1	0.3362	0.2540	0.3458	0.3009	0.3092	121	60	50	50	50	53
T2	0.2855	0.2427	0.2090	0.0000	0.1843	75	70	70	60	100	75
T3	0.0000	0.2352	0.4092	0.3427	0.2468	103	100	40	50	40	58
T4	0.0000	0.0000	0.3483	0.0000	0.0871	32	100	100	60	100	90
T5	0.3764	0.2642	0.3658	0.1912	0.2994	117	0	0	0	0	0
T6	0.3334	0.1802	0.2700	0.2668	0.2626	100	0	0	0	0	0
Avg	0.2219	0.1961	0.3247	0.1836	0.2316						
Peas											
T1	0.2657	0.1488	0.5034	0.4080	0.3315	69	50	60	30	30	43
T2	0.2053	0.0792	0.3437	0.0000	0.1571	32	60	70	60	100	73
T3	0.5449	0.6845	0.4525	0.5050	0.5467	100	30	20	20	20	23
T4	0.1657	0.1209	0.3241	0.5640	0.2937	61	70	60	60	60	63
T5	0.0211	0.7753	0.4888	0.6309	0.4790	87	80	0	0	0	20
T6	0.5289	0.8332	0.4391	0.4469	0.5620	100	0	0	0	0	0
Avg	0.2886	0.4403	0.4253	0.4258	0.3950						

Appendix Table 21. (continue).

Treatment	Fresh weight per plant (g)						Visual Injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.0847	0.0088	0.0000	0.0169	0.0276	9	70	80	100	80	83
T2	0.0000	0.0000	0.0373	0.0000	0.0093	4	100	100	90	100	98
T3	0.0180	0.1740	0.0360	0.2971	0.1313	44	90	40	80	10	55
T4	0.0477	0.0000	0.0000	0.0000	0.0119	4	80	100	100	100	95
T5	0.3349	0.3004	0.2580	0.2766	0.2925	103	0	0	0	0	0
T6	0.2913	0.2943	0.2498	0.3076	0.2858	100	0	0	0	0	0
Avg	0.1294	0.1296	0.0969	0.1497	0.1264						
Safflower											
T1	0.3627	0.0000	0.0000	0.4083	0.1928	56	60	100	100	50	78
T2	0.0000	0.2958	0.0000	0.0000	0.0740	26	100	60	100	100	90
T3	0.0000	0.0000	0.2500	0.2940	0.1360	42	100	100	50	30	70
T4	0.3561	0.0000	0.0000	0.0000	0.0890	25	70	100	100	100	93
T5	0.3732	0.4411	0.3133	0.3867	0.3786	117	0	0	0	0	0
T6	0.3653	0.2899	0.3249	0.3267	0.3267	100	0	0	0	0	0
Avg	0.2429	0.1711	0.1480	0.2360	0.1995						
Peas											
T1	0.4721	0.1172	0.2808	0.0000	0.2175	43	20	70	70	100	65
T2	0.1591	0.0000	0.2161	0.0000	0.0938	20	70	100	60	100	83
T3	0.1210	0.0000	0.2376	0.4344	0.1983	36	80	100	70	30	70
T4	0.4165	0.0000	0.0000	0.0247	0.1103	20	40	100	100	80	80
T5	0.4075	0.3581	0.1115	0.5443	0.3554	60	0	20	60	0	20
T6	0.5475	0.6178	0.4183	0.6667	0.5626	100	0	0	0	0	0
Avg	0.3540	0.1822	0.2107	0.2784	0.2563						

Appendix Table 22. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 114 days after the applications of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.1520	0.1380	0.2032	0.0902	0.1459	44	70	75	60	70	69
T2	0.0355	0.0712	0.1087	0.1561	0.0929	29	80	75	70	70	74
T3	0.1656	0.2178	0.2332	0.1843	0.2002	61	70	75	60	60	66
T4	0.0886	0.1745	0.0740	0.1263	0.1159	36	70	75	70	70	71
T5	0.3625	0.3049	0.2356	0.2638	0.2917	90	0	0	0	0	0
T6	0.3169	0.3230	0.3579	0.3070	0.3262	100	0	0	0	0	0
Avg	0.1869	0.2049	0.2021	0.1880	0.1955						
Safflower											
T1	0.6084	0.3928	0.2665	0.3966	0.4161	107	40	30	40	50	40
T2	0.3350	0.3926	0.0000	0.4061	0.2834	73	70	70	100	40	70
T3	0.4073	0.3785	0.3537	0.3918	0.3828	98	30	60	30	30	38
T4	0.1967	0.3975	0.3330	0.5097	0.3592	92	70	50	70	40	58
T5	0.3552	0.3597	0.4203	0.3060	0.3603	92	0	0	0	0	0
T6	0.3833	0.3904	0.4055	0.3931	0.3931	100	0	0	0	0	0
Avg	0.3810	0.3853	0.2965	0.4006	0.3658						

Appendix Table 22. (continue).

Treatment	Fresh weight per plant (g)					POC(%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.3298	0.3152	0.3876	0.2395	0.3180	102	0	10	5	30	11
T2	0.2904	0.3121	0.2472	0.3469	0.2992	98	30	40	40	40	38
T3	0.3696	0.2884	0.3599	0.2895	0.3269	104	30	30	10	40	28
T4	0.3228	0.2318	0.2586	0.2816	0.2737	87	40	30	30	50	38
T5	0.3834	0.3319	0.3358	0.3030	0.3385	109	0	0	0	0	0
T6	0.3840	0.2354	0.3489	0.3068	0.3188	100	0	0	0	0	0
Avg	0.3467	0.2858	0.3230	0.2946	0.3125						
Safflower											
T1	0.4297	0.0000	0.5087	0.4440	0.3456	85	0	100	0	0	25
T2	0.4758	0.3274	0.0000	0.4672	0.3176	90	0	20	100	0	30
T3	0.3884	0.3022	0.4906	0.4956	0.4192	111	0	20	0	20	10
T4	0.2608	0.4312	0.3365	0.3809	0.3524	99	30	0	20	25	19
T5	0.3020	0.3499	0.4826	0.4139	0.3871	104	0	0	0	0	0
T6	0.3880	0.2841	0.4566	0.3783	0.3768	100	0	0	0	0	0
Avg	0.3741	0.2825	0.3792	0.4300	0.3665						

Appendix Table 23. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 220 days after the applications of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.5077	0.5690	0.4481	0.6666	0.5479	130	10	0	10	0	5
T2	0.4765	0.6327	0.3824	0.3358	0.4569	107	30	20	10	20	20
T3	0.3519	0.2993	0.3231	0.4352	0.3524	83	10	0	10	10	8
T4	0.3068	0.5898	0.5347	0.4860	0.4793	114	30	30	10	10	20
T5	0.3621	0.5983	0.6969	0.4161	0.5184	121	0	0	0	0	0
T6	0.5223	0.3831	0.4837	0.3665	0.4389	100	0	0	0	0	0
Avg	0.4212	0.5120	0.4782	0.4510	0.4656						
Safflower											
T1	0.3490	0.3407	0.4690	0.4752	0.4085	87	0	0	0	10	3
T2	0.5553	0.5905	0.5442	0.4987	0.5472	115	0	0	10	10	5
T3	0.4493	0.4319	0.6015	0.3658	0.4621	99	0	0	0	10	3
T4	0.7641	0.5378	0.4534	0.5344	0.5724	118	0	10	10	10	8
T5	0.5933	0.4884	0.5141	0.5278	0.5309	111	0	0	0	0	0
T6	0.5140	0.5292	0.3944	0.4974	0.4838	100	0	0	0	0	0
Avg	0.5375	0.4864	0.4961	0.4832	0.5008						
Peas											
T1	1.1060	1.0604	1.0495	1.4937	1.1774	115	0	0	10	0	3
T2	1.0082	1.1703	0.0000	1.5938	0.9431	80	0	0	100	0	25
T3	0.9343	0.9814	1.7280	1.2074	1.2128	128	0	0	0	0	0
T4	0.9331	1.1800	2.1020	1.5533	1.4416	153	20	0	0	0	5
T5	1.2852	1.3439	1.2154	1.2000	1.2611	121	0	0	0	0	0
T6	1.3626	1.7000	0.6882	0.9114	1.1656	100	0	0	0	0	0
Avg	1.1049	1.2393	1.1305	1.3266	1.2003						

Appendix Table 23. (continue).

Treatment	Fresh weight per plant (g)					POC(%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.5164	0.7043	0.5652	0.7469	0.6332	123	0	0	0	0	0
T2	0.6879	0.7445	0.3626	0.6665	0.6154	125	0	0	10	0	3
T3	0.3889	0.4914	0.5681	0.6650	0.5284	92	0	0	0	0	0
T4	0.7926	0.4531	0.6500	0.5310	0.6067	117	0	0	0	0	0
T5	0.5658	0.3995	0.7479	0.4978	0.5528	103	0	0	0	0	0
T6	0.4487	0.3948	0.6893	0.6425	0.5438	100	0	0	0	0	0
Avg	0.5667	0.5313	0.5972	0.6250	0.5801						
Safflower											
T1	0.6418	0.5428	0.4470	0.5064	0.5345	127	0	0	0	0	0
T2	0.6431	0.4918	0.0000	0.5165	0.4129	94	0	0	100	0	25
T3	0.5513	0.2438	0.5649	0.5568	0.4792	121	0	30	0	0	8
T4	0.6208	0.4343	0.5678	0.5372	0.5400	132	0	0	0	0	0
T5	0.5674	0.6023	0.4910	0.5984	0.5648	137	0	0	0	0	0
T6	0.5522	0.5413	0.3628	0.3035	0.4400	100	0	0	0	0	0
Avg	0.5961	0.4761	0.4056	0.5028	0.4952						
Peas											
T1	0.6628	0.9061	1.0596	2.0037	1.1581	102	0	0	0	0	0
T2	1.8324	1.3176	0.8195	0.9381	1.1227	89	0	0	0	0	0
T3	1.2389	1.1719	1.5248	1.1593	1.2737	94	0	0	0	0	0
T4	1.4369	1.3541	1.1470	0.6018	1.1350	78	0	0	0	0	0
T5	0.8997	1.3651	1.4555	1.3610	1.2703	99	0	0	0	0	0
T6	1.9104	1.3550	1.8768	0.8035	1.4864	100	0	0	0	0	0
Avg	1.3302	1.2450	1.3139	1.1446	1.2580						

Appendix Table 24. Fresh weight and visual injury of the indicator species planted in soil samples collected at 287 days after the application of clopyralid, XRM-3785, and 2,4-D on September 12,1984.

Treatment	Fresh weight per plant (g)						Visual injury (%)			
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4
Depth 1										
Lentil										
T1	0.4436	0.4019	0.4050	0.2765	0.3818	70	5	0	0	0
T2	0.5895	0.4288	0.6331	0.3049	0.4891	89	10	5	0	5
T3	0.5560	0.5498	0.5798	0.2756	0.4903	90	0	0	0	0
T4	0.7081	0.4576	0.5065	0.5785	0.5627	102	10	5	5	0
T5	0.7064	0.5537	0.6844	0.4109	0.5889	108	0	0	0	0
T6	0.5199	0.5012	0.5930	0.5976	0.5529	100	0	0	0	0
Avg	0.5873	0.4822	0.5670	0.4073	0.5110					
Safflower										
T1	0.7771	0.7602	0.7275	0.4436	0.6771	101	0	0	0	0
T2	0.6230	0.7216	0.8741	0.7076	0.7316	110	0	0	0	5
T3	0.6332	0.6215	0.6751	0.5536	0.6209	93	0	0	0	0
T4	0.7613	0.6828	0.6014	0.7248	0.6926	106	0	5	5	0
T5	0.5371	0.6362	0.6993	0.6775	0.6375	97	0	0	0	0
T6	0.6673	0.6661	0.7792	0.5621	0.6687	100	0	0	0	0
Avg	0.6665	0.6814	0.7261	0.6115	0.6714					
Peas										
T1	1.8148	2.1788	1.5907	1.7340	1.8300	91	0	0	0	0
T2	2.1573	1.2299	1.8442	1.4645	1.6740	85	0	0	0	0
T3	2.2509	2.0558	2.2934	1.3257	1.9815	100	0	0	0	0
T4	2.1379	2.2824	2.2548	2.3691	2.2611	112	10	0	0	0
T5	1.6770	2.3238	2.5973	2.0523	2.1626	107	0	0	0	0
T6	1.7089	2.1379	2.0468	2.2386	2.0331	100	0	0	0	0
Avg	1.9578	2.0348	2.1045	1.8640	1.9904					

Appendix Table 25. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 0 days after the applications of clopyralid, XRM-3785, and 2,4-D on April 4,1985.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T6	0.1516	0.4425	0.2403	0.2843	0.2797	100	0	0	0	0	0
Avg	0.0253	0.0738	0.0401	0.0474	0.0466						
Safflower											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T6	0.3078	0.2218	0.2960	0.0000	0.2064	100	0	0	0	0	0
Avg	0.0513	0.0370	0.0493	0.0000	0.0344						
Peas											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.1405	0.1138	0.0000	0.0636	10	100	90	90	100	95
T6	0.5827	0.6285	0.6738	0.2905	0.5439	100	0	0	0	0	0
Avg	0.0971	0.1282	0.1313	0.0484	0.1013						

Appendix Table 25. (continue)

Treatment	Fresh weight per plant (g)						Visual Injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.2169	0.2927	0.2154	0.2561	0.2453	97	0	0	0	0	0
T2	0.2868	0.2548	0.2478	0.2634	0.2641	105	0	0	0	0	0
T3	0.3020	0.2313	0.2518	0.2469	0.2580	102	0	0	0	0	0
T4	0.2756	0.2284	0.2244	0.2358	0.2411	96	0	0	0	0	0
T5	0.2450	0.2444	0.2274	0.2528	0.2424	96	0	0	0	0	0
T6	0.2442	0.2438	0.2816	0.2473	0.2542	100	0	0	0	0	0
Avg	0.2618	0.2498	0.2414	0.2504	0.2509						
Safflower											
T1	0.2817	0.3645	0.2769	0.3251	0.3121	88	0	0	0	0	0
T2	0.3337	0.3016	0.2615	0.3353	0.3080	89	0	0	0	0	0
T3	0.3905	0.1107	0.3154	0.2820	0.2747	83	0	0	0	0	0
T4	0.3645	0.3438	0.2650	0.2789	0.3131	90	0	0	0	0	0
T5	0.3370	0.3884	0.3108	0.3204	0.3392	96	0	0	0	0	0
T6	0.2944	0.4436	0.3654	0.3294	0.3582	100	0	0	0	0	0
Avg	0.3336	0.3254	0.2992	0.3119	0.3176						
Peas											
T1	0.6038	0.4442	0.6210	0.6159	0.5712	103	0	0	0	0	0
T2	0.6995	0.5662	0.8070	0.6442	0.6792	122	0	0	0	0	0
T3	0.8263	0.0000	0.6773	0.5943	0.5245	98	0	100	0	0	25
T4	0.4747	0.5318	0.5919	0.7435	0.5855	105	0	0	0	0	0
T5	0.0000	0.5920	0.4151	0.4063	0.3533	60	100	0	0	0	25
T6	0.4951	0.6359	0.6181	0.5122	0.5653	100	0	0	0	0	0
Avg	0.5166	0.4617	0.6217	0.5861	0.5465						

Appendix Table 26. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 14 days after the applications of clopyralid, XRM-3785, and 2,4-D on April 4,1985.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0055	0.0000	0.0000	0.1150	0.0301	9	95	100	100	60	100
T6	0.2590	0.2978	0.3130	0.3253	0.2988	100	0	0	0	0	0
Avg	0.0441	0.0496	0.0522	0.0734	0.0548						
Safflower											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.1341	0.2503	0.1712	0.1389	37	100	90	80	90	90
T6	0.4084	0.4092	0.3634	0.3634	0.3861	100	0	0	0	0	0
Avg	0.0681	0.0906	0.1023	0.0891	0.0875						
Peas											
T1	0.0000	0.0835	0.0928	0.0000	0.0441	6	100	90	90	100	95
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	0.2528	0.0000	0.3113	0.1410	19	100	50	100	70	80
T6	0.7917	0.7887	0.8056	0.7095	0.7739	100	0	0	0	0	0
Avg	0.1320	0.1875	0.1497	0.1701	0.1598						

Appendix Table 26. (continue)

Treatment	Freshweight per plant (g)					POC(%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.2625	0.2689	0.2736	0.3193	0.2811	99	40	0	0	0	10
T2	0.2821	0.2278	0.2887	0.1552	0.2385	84	0	20	10	40	18
T3	0.2914	0.2715	0.3418	0.2455	0.2876	101	0	10	0	20	8
T4	0.0570	0.1969	0.3160	0.1543	0.1811	63	80	20	0	50	38
T5	0.3060	0.2809	0.2403	0.2449	0.2680	95	0	0	0	0	0
T6	0.2860	0.2377	0.3195	0.3018	0.2863	100	0	0	0	0	0
Avg	0.2475	0.2473	0.2967	0.2359	0.2571						
Safflower											
T1	0.4366	0.2826	0.4430	0.4416	0.4010	108	30	0	0	0	8
T2	0.4357	0.3920	0.3581	0.3624	0.3781	105	0	0	20	20	10
T3	0.2716	0.0000	0.3530	0.2811	0.2264	59	0	100	0	30	33
T4	0.3702	0.3845	0.3422	0.3057	0.3507	95	30	20	0	40	23
T5	0.3340	0.1622	0.2755	0.3853	0.2893	78	0	0	0	0	0
T6	0.3932	0.3361	0.4381	0.3208	0.3739	100	0	0	0	0	0
Avg	0.3735	0.2600	0.3683	0.3507	0.3381						
Peas											
T1	0.7971	0.6706	0.7692	0.8581	0.7738	113	10	0	0	0	3
T2	0.8350	0.8041	0.6253	0.9087	0.7933	117	0	0	10	0	3
T3	0.7152	0.6663	0.7350	0.8257	0.7356	108	0	0	0	0	0
T4	0.7602	0.7448	0.5751	0.5930	0.6683	97	10	0	0	10	5
T5	0.1995	0.6837	0.6989	0.7772	0.5898	89	0	0	0	0	0
T6	0.7711	0.6754	0.7790	0.5636	0.6973	100	0	0	0	0	0
Avg	0.6797	0.7075	0.6971	0.7544	0.7097						

Appendix Table 27. Fresh weight and visual injury of the indicator species planted in soil samples collected from different depths at 28 days after the applications of clopyralid, XRM-3785, and 2,4-D on April 4,1985.

Treatment	Fresh weight per plant (g)						Visual injury (%)				
	R1	R2	R3	R4	Avg	POC(%)	R1	R2	R3	R4	Avg
Depth 1											
Lentil											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.2034	0.5000	0.3293	0.3522	0.3462	72	50	0	0	0	13
T6	0.5593	0.5085	0.4828	0.4059	0.4891	100	0	0	0	0	0
Avg	0.1271	0.1681	0.1354	0.1264	0.1392						
Safflower											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.3678	0.4061	0.4309	0.2319	0.3592	69	10	10	0	0	5
T6	0.5443	0.4974	0.5274	0.5230	0.5230	100	0	0	0	0	0
Avg	0.1520	0.1506	0.1597	0.1258	0.1470						
Peas											
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T3	0.0777	0.0000	0.0000	0.0000	0.0194	2	90	100	100	100	98
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0	100	100	100	100	100
T5	0.0000	1.7669	1.5492	1.2943	1.1526	112	100	0	0	0	25
T6	1.1509	1.3517	0.8603	0.9576	1.0801	100	0	0	0	0	0
Avg	0.2048	0.5198	0.4016	0.3753	0.3754						

Appendix Table 27. (continue).

Treatment	Fresh weight per plant (g)					POC(%)	Visual Injury (%)				
	R1	R2	R3	R4	Avg		R1	R2	R3	R4	Avg
Depth 2											
Lentil											
T1	0.5288	0.5555	0.4097	0.3100	0.4510	112	0	0	0	15	4
T2	0.2266	0.7067	0.4028	0.0900	0.3569	95	30	10	0	90	33
T3	0.5441	0.3229	0.5683	0.4059	0.4603	116	20	40	0	20	20
T4	0.2533	0.2868	0.2223	0.4593	0.3054	79	70	30	50	10	40
T5	0.6493	0.3578	0.5572	0.7407	0.5763	145	0	0	0	0	0
T6	0.7033	0.3734	0.2996	0.3615	0.4345	100	0	0	0	0	0
Avg	0.4842	0.4339	0.4100	0.3946	0.4307						
Safflower											
T1	0.4490	0.5590	0.5533	0.4913	0.5132	103	20	10	0	10	10
T2	0.4923	0.5321	0.4905	0.5676	0.5206	105	10	20	0	70	25
T3	0.6909	0.3334	0.4174	0.7015	0.5358	109	10	60	0	40	28
T4	0.5941	0.6238	0.4745	0.6063	0.5747	114	10	60	0	30	25
T5	0.5308	0.4110	0.5095	0.6061	0.5144	106	0	0	0	0	0
T6	0.6054	0.6251	0.4220	0.4117	0.5161	100	0	0	0	0	0
Avg	0.5604	0.5141	0.4779	0.5641	0.5291						
Peas											
T1	1.4027	0.8427	0.9172	0.9431	1.0264	89	0	0	0	0	0
T2	1.2260	1.4600	0.0000	1.5316	1.0544	92	10	0	100	30	35
T3	1.5262	0.0000	1.4893	0.2770	0.8231	69	10	100	0	70	45
T4	1.4333	0.7811	1.1340	1.1293	1.1194	97	10	30	0	30	18
T5	0.2957	1.0289	1.2573	0.8929	0.8687	83	80	0	0	0	20
T6	1.5527	0.9545	0.9800	1.1436	1.1577	100	0	0	0	0	0
Avg	1.2394	0.8445	0.9630	0.9863	1.0083						

Appendix Table 28. Fresh weight of the indicator species planted in soil samples collected from different depths at 56 days after the applications of clopyralid, XRM-3785, and 2,4-D on April 4,1985.

Treatment	Fresh weight per plant (g)					POC(%)
	R1	R2	R3	R4	Avg	
Depth 1						
Lentil						
T1	0.0000	0.0000	0.0000	0.0000	0.0000	0
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0
T5	0.0000	0.0000	0.2996	0.1515	0.1128	29
T6	0.6165	0.5527	0.3457	0.5339	0.5122	100
Avg	0.1028	0.0921	0.1076	0.1142	0.1042	
Safflower						
T1	0.3086	0.0000	0.0000	0.0000	0.0772	13
T2	0.0000	0.0000	0.0000	0.0000	0.0000	0
T3	0.0000	0.0000	0.0000	0.0000	0.0000	0
T4	0.0000	0.0000	0.0000	0.0000	0.0000	0
T5	0.0000	0.4765	0.5258	0.6560	0.4146	70
T6	0.5825	0.4693	0.6556	0.6823	0.5974	100
Avg	0.1485	0.1576	0.1969	0.2213	0.1815	
Peas						
T1	0.3871	0.0000	0.0000	0.2171	0.1511	8
T2	0.2095	0.8815	0.4944	0.0000	0.3964	18
T3	0.4737	1.5663	0.0000	0.4356	0.6189	29
T4	0.0000	0.1532	0.0000	0.1998	0.0883	4
T5	1.7814	1.7913	1.7908	1.9187	1.8206	88
T6	1.6725	2.3185	2.3961	2.0921	2.1198	100
Avg	0.7540	1.1185	0.7802	0.8106	0.8659	

Appendix Table 28. (continue)

Treatment	Fresh weight per plant (g)					POC(%)
	R1	R2	R3	R4	Avg	
Depth 2						
Lentil						
T1	0.0000	0.3216	0.3189	0.5442	0.2962	65
T2	0.1885	0.2489	0.2511	0.3677	0.2641	56
T3	0.5797	0.3911	0.3879	0.5570	0.4789	99
T4	0.0264	0.2837	0.3954	0.3673	0.2682	58
T5	0.3357	0.3939	0.7010	0.4116	0.4606	97
T6	0.5451	0.4973	0.4518	0.4407	0.4837	100
Avg	0.2792	0.3561	0.4177	0.4481	0.3753	
Safflower						
T1	0.6160	0.5736	0.6329	0.8115	0.6585	106
T2	0.6193	0.5307	0.6248	0.8831	0.6645	107
T3	0.6746	0.6492	0.6550	0.6774	0.6646	105
T4	0.6387	0.5603	0.8307	0.5651	0.6487	104
T5	0.7728	0.5494	0.6181	0.5857	0.6315	100
T6	0.6606	0.7781	0.5605	0.5719	0.6428	100
Avg	0.6637	0.6069	0.6537	0.6825	0.6518	
Peas						
T1	1.4848	2.2026	2.2142	2.0977	2.0000	94
T2	2.2177	2.1619	2.1774	2.5008	2.2645	106
T3	2.4648	1.5315	1.9347	2.1314	2.0156	94
T4	2.3710	2.0967	2.3652	1.6224	2.1138	98
T5	2.2892	1.8388	1.5546	1.9080	1.8977	88
T6	2.4245	2.0754	2.0419	2.0671	2.1522	100
Avg	2.2087	1.9845	2.0480	2.0546	2.0741	

Appendix Table 29. Clopyralid concentrations (ppm) in soil at different depths and various sampling dates determined by the three indicator species following the application rate of 0.56 kg/ha on September 12,1984.

Depth (cm)	Lentil				Safflower				Peas			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
0 DAT												
0-10	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
10-20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14 DAT												
0-10	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125
10-20	0.023	0.012	0.047	0.016	0.047	0.094	0.047	0.023	0.023	0.023	0.023	0.023
34 DAT												
0-10	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.250	>.250	>.250	>.250
10-20	0.047	0.023	0.012	0.047	0.047	0.023	0.012	0.047	0.250	0.023	0.012	0.047
54 DAT												
0-10	0.023	0.047	0.047	0.023	0.023	0.047	0.023	0.047	0.047	0.047	0.023	0.047
10-20	0.023	0.047	0.250	0.047	0.023	0.125	0.125	0.023	0.012	0.094	0.094	0.250
114DAT												
0-10	0.023	0.047	0.023	0.023	0.023	0.047	0.094	0.094	-	-	-	-
10-20	0.002	0.006	0.002	0.006	0.002	-	0.002	0.012	-	-	-	-
220 DAT												
0-10	0.012	0.012	0.012	0.012	0.006	0.006	0.006	0.006	0.006	0.002	0.006	0.006
10-20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
287 DAT												
0-10	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix Table 30. Clopyralid concentrations in soil at different depths and various sampling dates determined by the three indicator species following the application rate of 1.12 kg/ha on September 12,1984.

Depth	Lentil				Safflower				Peas			
(cm)	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
0 DAT												
0-10	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
10-20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14 DAT												
0-10	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.250	>.250	>.250	>.250
10-20	0.125	0.023	0.023	0.023	0.094	0.023	0.047	0.023	0.047	0.023	0.023	0.023
34 DAT												
0-10	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.125	>.250	>.250	>.250	>.250
10-20	0.125	0.125	0.125	0.125	0.094	0.047	0.125	0.125	0.047	0.047	0.250	0.094
54 DAT												
0-10	0.047	0.047	0.023	0.188	0.047	0.047	0.047	0.125	0.047	0.047	0.047	-
10-20	0.250	0.250	0.047	0.250	0.125	0.047	0.125	0.125	0.094	0.250	0.047	0.250
114 DAT												
0-10	0.047	0.047	0.047	0.023	0.094	0.094	0.125	0.047	-	-	-	-
10-20	0. 12	0.012	-	0.012	0.012	0.023	-	0.012	-	-	-	-
220 DAT												
0-10	0.023	0.012	0.012	0.012	0.006	0.006	0.006	0.012	0.002	0.012		0.012
10-20	0.000	0.000	0.000	0.000	0.002	0.000	-	0.002	0.000	0.000	0.000	0.000
287 DAT												
0-10	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000