THESIS

This is to certify that the

thesis entitled

INVESTIGATION OF FACTORS WHICH CONTRIBUTE TO ASPARAGUS (ASPARAGUS OFFICINALIS L.) DECLINE IN MICHIGAN

presented by

RICHARD MARTIN HODUPP

has been accepted towards fulfillment
of the requirements for

M.S. degree in Horticulture

Major professor
Alan R. Putnam

Date 8-15-83

INVESTIGATION OF FACTORS WHICH CONTRIBUTE TO ASPARAGUS (*ASPARAGUS OFFICINALIS* L.) DECLINE IN MICHIGAN

By

Richard Martin Hodupp

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

1983

ABSTRACT

INVESTIGATION OF FACTORS WHICH CONTRIBUTE TO ASPARAGUS (*ASPARAGUS OFFICINALIS* L.) DECLINE IN MICHIGAN

by

Richard Martin Hodupp

A survey of 26 fields from the two major asparagus (*Asparagus officinalis* L.) growing areas of Michigan indicated that *Fusarium* root rot, low soil pH, soil compaction, herbicide overdoses, and toxic asparagus residues (allelopathy) contribute to asparagus decline. In the greenhouse, the soil pH most suitable for both fern growth and crown development was 7.5 while many commercial fields had pH's below 5.5. Field applications of hydrated lime were effective for rapid correction of soil pH (1.7 to 2.2 units) in eleven months. Induced soil compaction (2,727 kg) reduced asparagus growth. Of four herbicides tested, diuron was found to be safest to asparagus based upon both crown and fern weights. Soil bioassays indicated that terbacil was the most persistent and moved the deepest (61 cm) over a two year period. Asparagus root residues while inhibitory to asparagus growth were relatively short lived.

To Patti

ACKNOWLEDGMENTS

To Dr. A.R. Putnam, I express my gratitude and appreciation for his support and guidance during this project, and for his assistance in preparing this manuscript.

To Dr. Hugh Price and Dr. A.J. Smucker, members of my examining committee, I extend my appreciation for their guidance and evaluation of this manuscript.

To everyone involved in providing me with the moral, physical, and/or financial support necessary for the completion of this undertaking, my deepest thanks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGRUES

INTRODUCTION

In 1980, Michigan ranked third in asparagus production nationally with 19,500 acres being harvested at a value of $12,014,000. The asparagus grown in Michigan has been utilized primarily for processing with a recent increase in fresh market production. (19) In recent years, Michigan asparagus growers have seen a gradual decline in average yield of asparagus per acre, from 1474 pounds per acre in 1972, to 1200 pounds per acre in 1980. (19) A decrease in field longevity has also been noted by growers.

In response to the asparagus growers' concern for this reduction in yield, a survey of 26 asparagus fields was conducted in Oceana and Van Buren Counties in 1978. Areas of interest were the general cultural practices followed, varieties planted, soil pH, number of crowns per acre, crown depth, spears per crown, herbicides used, soil compaction, and the number of Fusarium infected crowns per sampled area.

Studies were also initiated to determine the effects of soil pH, herbicides, soil compaction, and allelopathy upon asparagus growth, both in the field and in the greenhouse. The objectives were to determine reasons for decreased longevity of plantings and to evaluate selected procedures for alleviating decline problems.

CHAPTER 1

LITERATURE REVIEW

I. Effect of liming materials on asparagus soil pH and effect of soil pH on young asparagus fern growth and crown development.

The permissible soil pH range recommended for asparagus culture on mineral soils has been 6.0 to 8.0. (5) It has been found on sandy soil, with a high organic matter content, that asparagus yields are better at a pH of 7.5 than 5.7 (55% increase). (11)

The hydroxide form of dolomitic limestone results in a greater effectiveness in adjusting soil pH to a depth of 30.5 cm than does other forms of limestone. (8) There is no apparent correlation with rainfall and the effect of dolomitic limestone on soil pH. (33) The finer the grade of limestone the more effective it will be in benefitting plant growth in a shorter period of time. (1 31) While the coarser lime is slower in its action, it remains in the soil longer and will be effective for a greater number of years. (1 32)

Seasonal variability of soil pH has been determined to be a factor in Michigan soils. (6) The preparation of the soil sample, the method utilized to determine the soil pH,

as well as the time of year in which the soil sampling was taken should be considered when comparing soil pH results. (6)

II. Effect of soil compaction on plant growth.

Several studies have been conducted to determine the effects of soil moisture, fertility level, and degree of soil compaction on plant growth. (2 11 21 28 29) At best, it has been difficult to separate out the effects of the different physical properties.

In sugar beets, it has been found that the amount of soil compaction necessary to effect seed moisture absorption and seedling emergence is dependent upon the soil moisture and the point of application of the pressure. (28) Possible justification for this has been the reduced rate of flow of moisture and gases and the quantity available to the seed, or, as the soil is compacted, its mechanical strength was increased, thus increasing the resistance to penetration by the seedling.

In field corn, Phillips (21) found that soil compaction reduced stands of corn and increased mechanical impedance to root growth. Also, large differences in air permeability were found between compacted and non-compacted soils at the 0 - 7 cm depth.

In an asparagus zero-tillage test, in August of the third season, soil compaction readings collected with a penetrometer indicated a significant difference between

zero-tillage spring tilled plots and the plot receiving two tillage operations. (23) Another plot treated with the same methods exhibited no significant differences. The only identifiable difference was the soil moisture content. The zero-tillage plots had a higher soil moisture content.

The lack of sufficient soil aeration and either excessive soil compaction can be detrimental to the overall growth of carrots. (20) It has been determined that soil compaction can be created by natural conditions, poor drainage, excessive tillage, cropping systems utilized, untimely field operations, and farm implement design as well as wheel slippage. (11 24) Soil compaction due to excessive tillage and traffic has been found to reduce sugarbeet yields by 74%. (27) In addition, minimum tillage treatments were found to provide a soil environment which promoted shoot and root growth. (27)

III. Movement and persistence of herbicides in the soil.

Differential herbicide movement and persistence in the soil has been attributed to several factors. Factors considered important with diuron, metribuzin, simazine, and terbacil are organic matter content, soil pH, and water solubility. (4 14 25 35) The amount of movement and persistence of each herbicide is particularly dependent upon the absorption characteristics of that particular compound.

Simazine movement in the soil due to water has been found to be minimal. (25) Oats and soybean growth in

soils sampled 15.2 and 22.9 cm in depth after simazine treatment at 2.2 and 4.5 kg/ha were not different from untreated checks. (25) The effect of soil pH on simazine phytotoxicity appears insignificant. (4) Upchurch (34) found that for each 1% increase in soil organic matter a 0.46 kg/ha increase in simazine was required to maintain 50% grass control. Simazine has been found to be more effective in controlling weeds in asparagus when applied so it is present during the early germination period of weed seeds. (35)

Terbacil has provided excellent full season weed control in asparagus. (35) In light textured soils, terbacil has been determined to cause injury to asparagus fern when applied at 2.2 kg/ha. (35) With a water solubility of 710 ppm, and with less adsorption on soil colloids than diuron or simazine it is more readily leached than either of those compounds. (10 37)

With metribuzin, leaching, and crop injury have been found to be greater at higher pH levels in the soil. (14) The longevity of phytotoxicity of metribuzin depends upon the soil type, while the soil per se has little effect on the rate of degradation. (26) Metribuzin has a water solubility fo 1200 ppm.

Diuron, which has a water solubility of 42 ppm, has a soil adsorption of 4.0 - 5.2 ppm on a Keyport silt loam which is an indication of low leachability. (10 37) Diuron has been found to degrade rapidly as temperatures increase. (18)

IV. Effect of asparagus residues on young asparagus crowns.

Etiolated tissue from young asparagus shoots has been found to yield a growth regulating compound, asparagusic acid, which will inhibit completely the growth of roots and hypocotyls of lettuce. (13) Asparagusic acid was also tested with seedlings of rice, rape, radish, carrot, and barnyard grass, and it consistently inhibited the growth of all of them. (13) Asparagus tissue has also been found to inhibit seed germination and asparagus seedling growth. (15) These findings are not peculiar to asparagus as the existence of allelopathy in a multitude of crops has been well documented over the past few decades. (22)

The optimum length of harvest to maximize yields for asparagus is 8 weeks. (7 30 36) The time of initiation of harvest on subsequent yields and number of weeks harvested has been determined to be: 0 harvest the first year after planting; 2 weeks after the second year; 4 weeks after the third year; and 8 weeks each succeeding year. (16 17)

CHAPTER 2

A SURVEY OF THE STATUS OF ASPARAGUS FIELDS IN MICHIGAN

Materials and Methods

This survey was performed in the two largest asparagus producing counties in Michigan (Oceana and Van Buren), after harvest had been completed in 1978. Items surveyed were crown depth, spears per crown, crowns per hectare, fern weight per hectare, soil pH, and per cent *Fusarium* infestation per sampled area. Other information surveyed included weather data for Oceana and Van Buren Counties for the months of April and May for the years 1971 through 1981.

Asparagus growers in Van Buren and Oceana Counties were asked to provide field history data from the periods previous five years concerning yield, tillage practices, herbicides used, and insecticides used. Information on age of planting, depth the crowns were planted, spacing in the rows and between the rows, as well as the number of crowns per acre were also provided by the growers. Nineteen growers from Oceana County and seven growers from Van Buren County were selected by the County Extension Director for this survey.

Crown depths were determined by excavating to the rhizome of four crowns randomly selected within a field. Depth was recorded as that distance from the soil surface to the top of the rhizome.

The average number of spears per crown was calculated by counting the number of marketable sized butts (.95 cm diameter or larger) on ten crowns from five randomly selected sites within a field in the summer of 1978.

The average number of crowns per 7.6 meters of row were determined by randomly selecting six sites and counting the number of crowns producing marketable spears within that area in the summer of 1978.

The average fern weight per 7.6 meters was determined by randomly selecting five sites in the field and harvesting all top growth within that area. The fresh weight of the fern was obtained with a spring-type scale. Fern was collected in the fall of 1978, after the asparagus had ceased growth.

Soil pH was determined by taking five soil samples 15.2 cm deep, thoroughly mixing those together and using a sub-soil sample for analysis. Soil pH was determined by the Michigan State University Soil Testing Laboratory.

The degree of Fusarium infestation was determined by visually inspecting only the 19 different fields in Oceana County. In each field, three repetitions of 25 consecutive crowns were examined for the presence of Fusarium.

Fusarium

Weather information was collected from the Annual Summaries of Climatological Data published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, for Hart, Michigan, in Oceana County, Bloomingdale, Michigan, in Van Buren County, and Eau Claire, Michigan in Berrien County.

Results and Discussion

Table 1 summarizes the data collected from the 26 sites. This data has been broken down into three categories: Highest, lowest, and average value obtained.

Of the 26 sampled sites, only four growers could provide detailed information beyond the number of acres in the field and the variety planted. Without in-depth field histories on yield it is questionable whether a grower can accurately determine if an asparagus field is indeed declining. In fact, he only seems to know that his total yields are more or less than in previous years.

Growers should keep individual records based upon the field and if a field is divided by planting year or variety, these differences should be accounted for. If this practice were followed a grower would have documentation which could be utilized in analyzing the operation and making sound management decisions.

As it stands, there is not sufficient grower information

Table 1. High, low, and average values from asparagus survey data for Oceana and Van Buren Counties

Area of Observation	Oceana County[1]			Van Buren County[2]		
	High	Low	Average	High	Low	Average
Crown Depth (cm)	17.2	6.4	10.7	14.9	9.9	12.2
Spears Per Crown	27.3	3.9	14.1	12.0	1.8	5.9
Crowns Per Hectare	11,384	3,319	7,208	13,755	7,874	11,571
Soil pH	6.9	4.0	5.4	6.9	3.7	5.6
Fern Weight Per Hectare	7,434	1,845	4,418	*	*	*
Percent Fusarium Infected Crowns	33.3	0	10.9	*	*	*

[1]Average of nineteen sampled plots

[2]Average of seven sampled plots

*Data not collected

to accurately determine what affect a given practice had upon their asparagus crops.

Crown Depth

Crown depths varied from a depth of 17.2 cm to 6.3 cm from the soil surface, and averaged 10.7 cm from the surface in Oceana County, and from 14.9 to 9.9 cm with an average of 12.2 cm from the surface in Van Buren County. (Table 1.) This depth was determined as that distance from the soil surface to the upper-most portion of the rhizome. The information provided by the growers, coupled with the information collected by our on-site examinations indicated that asparagus crowns are either not being planted as deeply as is recommended, they are growing upward, or soil is rapidly being eroded from the surface. Shallow planting could be a reason for the shorter life of an asparagus field today as compared to those planted in the early 1900's.

Spears Per Crown

The range in marketable spears per crown varied from a high of 27.3 spears per crown to a low of 3.9 with an average of 14.1 in Oceana County, and a high of 12.0 to a low of 1.8 with an average of 5.9 spears per crown in Van Buren County. (Table 1) These differences in numbers of spears per crown represent an 86% and 85% respective difference in yield potential between the high producing and low producing crowns.

When comparing crown depth with the number of marketable

spears per crown in the data collected from both counties, there was a significant positive correlation between the depth of a crown and the fern weight collected per plot. Hence, the deeper the crown, the greater the weight of the fern per crown.

Crowns Per Hectare

The average number of crowns per 7.6 meters was as high as 12 (11,384 per ha) and a low of 3.5 (3,319 per ha) with an average of 7.6 (7,208 per ha) in Oceana County and a high of 14.5 (13,755 per ha) and a low of 8.3 (7,874 per ha) with an average of 12.2 (11,571 per ha) found in Van Buren County. The USDA recommended crown spacing for green asparagus is .3 m spacing in rows 1.2 m apart or 28,653 crowns per hectare. (Table 1)

According to the 2 completed Van Buren County grower survey forms, the actual number of crowns planted was very similar to the recommended number. However, data collected during the survey indicated that in a 9 year old planting, approximately one-half of the crowns planted had either died or had grown into an adjoining crown thus making it impossible to distinguish between crowns. There could have been numerous reasons for this reduction including allelopathy, disease problems, or low soil pH.

Fern Weight Per Hectare

Dry fern weight was collected from 19 plots in Oceana County. Rather than harvest and record fern weights from

individual crowns, all fern weight from the 7.6 meter area was combined and recorded as a single unit.

The plot with the highest total fern weight also had the deepest crowns and the largest number of crowns per 7.6 meters. The fern weight amounted to 7,435 kg per ha. The lowest total fern weight amounted to 1,845 kg per ha. (Table 1)

Soil pH

In Oceana County, the soil pH of the plots surveyed varied from a high of 6.9 to a low of 4.0 with an average of 5.4. In Van Buren County, the soil pH ranged from 6.9 to a low of 3.7 with a 5.6 average. (Table 1) Interestingly enough was the fact that the high and low pH's did not appear to correlate with any of the other items surveyed. Two possible reasons for the reduced soil pH are: 1) the soil was not routinely tested for pH and sufficient lime was not applied, 2) lime that was applied could have been eroded away either by wind or water or, 3) repeated nitrogen fertilization aggravated the problem.

Percentage Fusarium Infestation

Of the 19 plots inspected for Fusarium infection, 9 showed symptoms of 19% or greater infestation with the highest infection rate being 33% of the crowns sampled. The field plot with the greatest number of crowns per hectare, largest amount of fern growth, and deepest crown also exhibited no symptoms of Fusarium. Of the 9 plots with

greater than a 10% infestation, 6 of those were California 309 variety, 2 were Viking variety, and 1 was Mary Washington variety. (Table 1) This leads to the conclusion that Mary Washington is more resistant to Fusarium infection than some of the Calfornia cultivars.

Weather Data

Weather data for the period 1971 through 1981 was analyzed for rainfall on an annual basis as well as the number of days with a temperature of less than 33°F. for the last 6 days of April and the month of May in the three (3) major asparagus producing counties in Michigan.

In analyzing the relationship of previous years rainfall with Michigan's average asparagus production per acre per year, there is no apparent correlation between amounts of precipitation and the annual yield of asparagus. (Figure 1) Although the rainfall varied from 39.4 cm above normal to 20.3 cm below normal in the asparagus growing areas, there was no obvious relationship with the next season's yield.

When comparing the number of days, from April 25 through May 25 each year 1972 through 1981, that the low daily temperature was less than 33°F., there does not appear to be a consistent asparagus decline that correlates to the last day of less than 33°F. per year. (Table 2) When one compares the total number of days between April 25 and May 31 yearly during which the temperature was less than 33°F., there appears to be a relationship between low

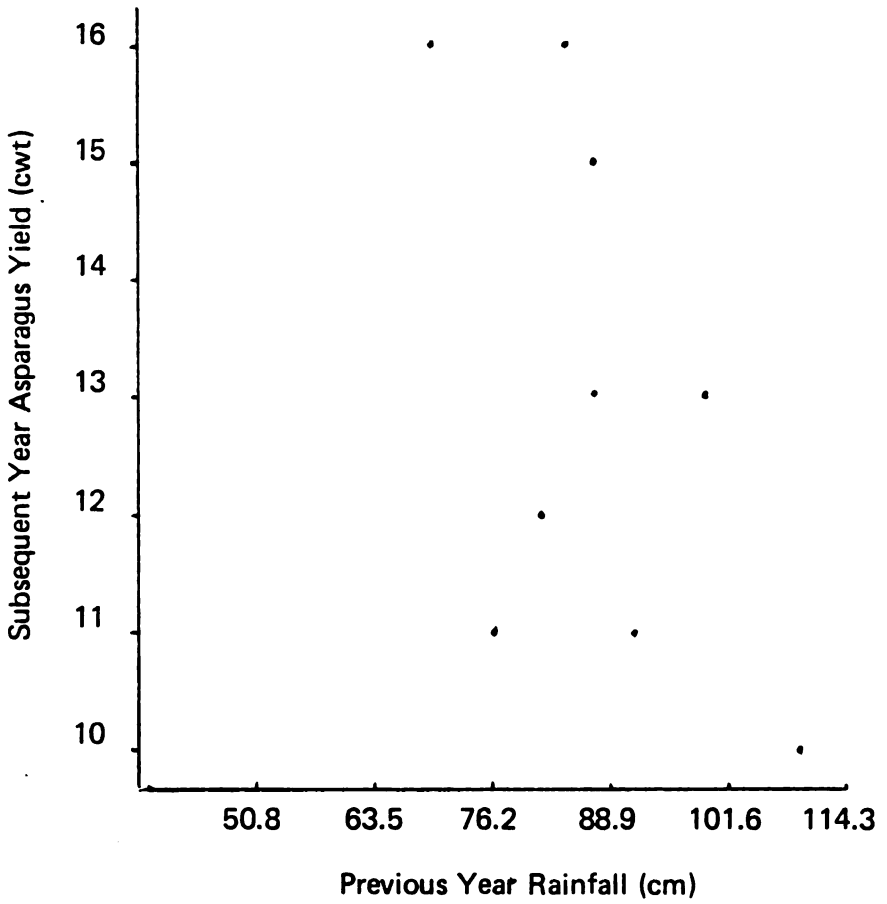

Figure 1. Effect of rainfall on annual asparagus production in Michigan (31)

Table 2. Last day of less than 33°F per year (31)

Year	Hart	Bloomingdale	Eau Claire	Yield Per Acre (cwt)
1971	5/22	5/28	5/3	
1972	5/10	5/10	4/26	15
1973	5/18	5/19	5/17	16
1974	5/10	5/11	5/7	15
1975	4/26	4/26	0	11
1976	5/19	5/20	5/8	10
1977	5/11	5/12	5/10	11
1978	5/6	5/6	5/3	13
1979	5/22	5/16	5/16	13
1980	4/26	5/10	4/26	12
1981	5/12	5/20	5/12	

temperatures and yield in 1976 and 1977, but when the entire period is considered, the correlations are not significant. (Table 3)

Table 3. Number of days from April 25 to May 31 when temperatures were less than 33°F. (31)

Year	Hart	Bloomingdale	Eau Claire	Total	Yield Per Acre (cwt)
1972	6	5	2	13	15
1973	6	8	1	15	16
1974	3	7	1	11	15
1975	1	1	0	2	11
1976	14	14	8	36	10
1977	9	9	4	22	11
1978	9	8	3	20	13
1979	7	9	9	25	13
1980	2	4	2	8	12
1981	7	11	5	23	

CHAPTER 3

MATERIALS AND METHODS

I. A. Influence of soil pH on asparagus crowns in the greenhouse. One year-old 'Mary Washington' crowns were obtained from a commercial asparagus grower in Oceana County, Michigan, weighed individually and grouped so there was less than 3 grams difference in the weight of each of the crowns utilized in any given treatment. Plants were held under a constant 16 hour photoperiod. Air temperature ranged from 16°C. to 28°C.

Each pot contained 10 kg of Emmet loamy sand soil (pH 4.5) imported from Oceana County, Michigan, for use in this experiment, plus sufficient powdered $Ca(OH)_2$ to theoretically adjust the soil pH to 5.5, 6.5, or 7.5, depending upon which treatment was being planted. Through preliminary testing it was determined that 4,885 kg/ha of $Ca(OH)_2$ was required to adjust the soil pH one unit in this soil type. The $Ca(OH)_2$ was thoroughly mixed into the soil using a cement mixer.

The crowns were planted 5 cm deep on August 8, 1980, in a 3.8 liter individual plastic pot containing the appropriate pH-adjusted soil placed in a randomzied complete block design. Crown weights were recorded before planting and at harvest. Fern and spear fresh weights were recorded

on harvest day. Harvest was conducted on October 25, 1980, 11 weeks after planting.

At that time, soil pH was determined using the electrometric method. One part soil and one part distilled water were mixed, and allowed to equilibrate for 24 hours prior to pH determination.

I. B. Influence of hydrated agricultural lime on soil pH in asparagus. Hydrated agricultural lime was applied to two asparagus sites in Oceana County, Michigan. Site #1 was an Emmet sandy loam soil with a beginning pH of 4.5 and site #2 was an Emmet loamy sand soil with a beginning pH of 4.8. The cultivar in each site was 'Mary Washington'. Each site was arranged in a randomized complete block design and received hydrated lime at 0; 6,713; 13,427; and 20,140 kg/ha.

Liming material was applied using a Gandy 4 foot push type spreader on April 10, 1980. Soil samples were collected using a hand held "T" bar type soil sampling device on March 21, 1981. Rainfall accumulation during this time period was 101 cm. (33)

To measure the effects of the liming materials on each treated area the following sampling procedures were followed:

(1) Two soil samples 1.9 cm x 30.5 cm were taken from each treated area.

(2) Each soil sample was divided into four depths (1.9 cm x 7.6 cm segments).

(3) The respective segments from each of the two samples from within the same treated area were mixed to form a composite soil sample.

(4) One part of this field moist composite sample was then mixed with one part distilled water and allowed to equilibrate for 24 hours before testing the pH using the electrometric method.

II. Soil compaction - field study. One year-old 'Mary Washington' asparagus crowns were planted on May 3, 1980, at a depth of 20.3 cm, 30.5 cm apart in the row. The plots were located in a Spinks loamy sand soil at the Horticulture Research Center.

After being covered with soil, the following compaction treatments were applied to areas 7.6 meters in length. The non-compacted treatment received nothing more than foot traffic to cover the crowns. Compaction was provided with either a Cub (IH) tractor which exerted 2.3 psi with the rear tires and 4.0 psi with the front tires or a Ford 5000 tractor which exerted 4.1 psi with the rear tires and 11.5 psi with the front tires. Compacting devices were driven directly over the rows twice, once from each direction, with both the front and rear tires covering the treated area.

III. A. Influence of herbicides on young crowns in the greenhouse. The following herbicides were applied at four rates to one year-old 'Mary Washington' asparagus crowns, planted into 3.8 l plastic pots. Prior to treatment,

each pot of soil was watered to field capacity. The soil type utilized was a Locke sandy loam.

Herbicide	Rates (kg/ha)
metribuzin	0.3, 0.6, 1.1, 2.2
terbacil	0.3, 0.6, 1.1, 2.2
simazine	0.6, 1.1, 2.2, 4.4
diuron	0.6, 1.1, 2.2, 4.4

Crowns were planted 10 cm below the surface and treated on August 1, 1980. A carbon dioxide backpack type sprayer was used to apply the herbicides. The entire plant was harvested September 20, 1980, 50 days after treatment.

Each asparagus crown was weighed both prior to planting and at harvest. At harvest, the fresh fern weights were also determined.

III. B. Movement and persistence of soil applied herbicides in asparagus fields. The following herbicides were applied in a randomized complete block design with 4 blocks and 9 treatments at 2 locations.

Herbicide	Preemergence kg/ha (AI)	Post-harvest kg/ha (AI)	Herbicide Per Year kg/ha (AI)
None	0	0	0
simazine	2.2	0	2.2
simazine	2.2	2.2	4.5
diuron	2.2	0	2.2
diuron	2.2	2.2	4.5
metribuzin	1.1	0	1.1
metribuzin	1.1	1.1	2.2
terbacil	1.1	0	1.1
terbacil	1.1	1.1	2.2

Asparagus field #1 was a 7 year-old planting of 'Mary Washington'. The Emmet loamy sand soil, .86% om, was dry during the preemergence herbicide application and moist during the post-harvest herbicide application.

Asparagus field #2 was a 15 year-old planting of 'Viking'. The Emmet sandy loam soil, 1.38% om, was dry during the preemergence herbicide application and moist during the post-harvest herbicide application.

The preemergence treatment was applied at both locations on April 28, 1978, while the post-harvest treatment was applied at both locations on June 19, 1978. Herbicides were applied using a backpack-type carbon dioxide powered sprayer.

From each treated plot, at both locations, soil samples were collected with a hydraulic sampler, in 30.5 cm increments to a depth of 91.4 cm. Soil samples were collected in June, 1978, prior to treatment, then in April and June, 1979, and December, 1979. A series of oat bioassays were conducted to determine the persistence and movement of the herbicides in the soil. The bioassays were conducted as follows: Twenty oat seeds were planted in cups containing approximately 0.5 kg of soil. After 21 days in a greenhouse at 25±5^{o}C., the plants were cut at the soil surface and dried for weight determination.

IV. A. Effect of asparagus residues on young asparagus crowns in the greenhouse. Crown and root material was collected from a 12 year-old planting of 'Mary Washington' at the Horticulutre Research Center. After shredding with a

flail type shredder one-half of the root material was soaked in water for a period of 48 hours and then drained over ¼-inch mesh screen prior to being incorporated into the soil. Soil was amended with leached and unleached root material, using a cement mixer, in the following proportions:

% Asparagus Root Material	Soil Weight (g)	Asparagus Root Weight (g)
20	3,840	960
10	4,320	480
5	4,560	240
2.5	4,680	120
Ø	4,800	Ø

One year-old 'Mary Washington' asparagus crowns obtained from a commercial grower in Oceana County, Michigan, were planted into individual 3.8 l pots containing a Locke sandy loam soil with various amounts of leached and unleached shredded asparagus root material. Plants were held under a constant 16 hour photoperiod. Air temperature ranged from 16°C. to 28°C. Fresh fern weights were recorded at harvest.

The experiments were sub-divided as follows:

(1) Asparagus grown 8 weeks, harvested at 4 week intervals with unleached root material in the growing media.

(2) Asparagus grown 8 weeks, harvested at 4 week intervals with leached root material in the growing media.

(3) Asparagus grown and harvested at the end of 8 weeks with unleached root material in the growing media.

(4) Asparagus grown and harvested at the end of 8 weeks with leached root material in the growing media.

Watering was accomplished such that the plants did not show symptoms of stress, and complete fertilizer solutions were applied at 2 week intervals with a proportioner.

IV. B. Effect of asparagus residues on young asparagus crowns - field study. 'Mary Washington' crowns obtained from a commercial asparagus grower in Oceana County, Michigan, were planted into a Spinks loamy sand on May 3, 1980. Prior to covering the crowns, which were placed 20 cm deep, treatments were assigned in a randomized complete block design with 4 blocks. Twelve year-old shredded asparagus root material was applied in the trench at rates of 0, 2, and 4 kg/6.1 meters of row. After covering with soil, the area received no further treatments during the growing season. The asparagus fern was harvested in November, 1980, after growth ceased and dry weights were obtained.

CHAPTER 4

RESULTS AND DISCUSSION

I. A. Influence of soil pH on asparagus crowns in the greenhouse. The asparagus fern and crowns were harvested and weighed individually 11 weeks after planting. At that time, the soil pH from each plot was recorded. The amount of fern growth increased with each pH treatment, however, crown growth exceeded the control only with a 7.5 pH. (Table 4)

The fern growth in all treatments was significantly greater than that obtained with the 4.5 pH control. Fern yields exhibited 31%, 33%, and 42% increases respectively with each pH treatment. (Table 4) These increases in fern growth compare favorably with work previously accomplished by Jorgensen and Henriksen. (11) This indicated that the higher the soil pH the greater the yield (kg/m^2) of asparagus.

The crown and fern weights obtained after $ca(OH)_2$ treatments were significantly different from those obtained with the control. Fern weights were increased 46-71% whereas the crown response was more variable. This indicates that crown growth may be more sensitive to pH in sandy soils with low organic matter content and that the optimum soil pH for crown development is near 7.5. This corresponds to recommendations by MSU Cooperative Extension Service which

Table 4. Influence of the soil amendment with $Ca(OH)_2$ on soil pH and asparagus growth

Desired Soil pH	Harvest Day Average Soil pH	Total Fern Weight (g)	Change in Crown Weight (g)
4.5	5.8	226	837
5.5	6.7	329**	659**
6.5	7.5	335**	908**
7.5	7.9	387**	597**
LSD at .01		11	61

identify the permissible soil pH range for asparagus as 6.3 to 7.8. (4)

Another consideration is that at the higher soil pH, 7.9, nutrients such as nitrogen, phosphorus, iron, manganese, boron, zinc, and possibly others were unavailable. (5)

The recorded soil pH on harvest day was higher than the anticipated soil pH. The control was 22% higher, treatment #2 was 18% higher, #3 was 13% higher, and #4 was 6% higher than anticipated. Some reasons for this occurrence are: 1) the theoretical amount of $Ca(OH)_2$ needed does not hold true for all soils; 2) the beginning soil pH was incorrectly identified; 3) the irrigation water effected the soil pH; 4) the buffering capacity of the soil was low thus causing the greater pH change to occur; or 5) the soil pH was not allowed to equilibrate prior to planting the asparagus crowns.

I. B. Influence of hydrated agricultural lime on soil pH in asparagus. The response to the hydrated lime by the Emmet loamy sand soils showed some similarity. (Figures 2 and 3) When final data was collected the top 7.6 cm of the control on site #2 was 1.5 pH units greater than the control of site #1. A major reason for this dramatic change was the grower applied an additional 4,490kg/ha of lime during the summer. This lime had little additional effect on those treatments receiving lime initially.

On site #1 the addition of lime at the higher rate had a significant effect on soil pH, down to 30.5 cm, when

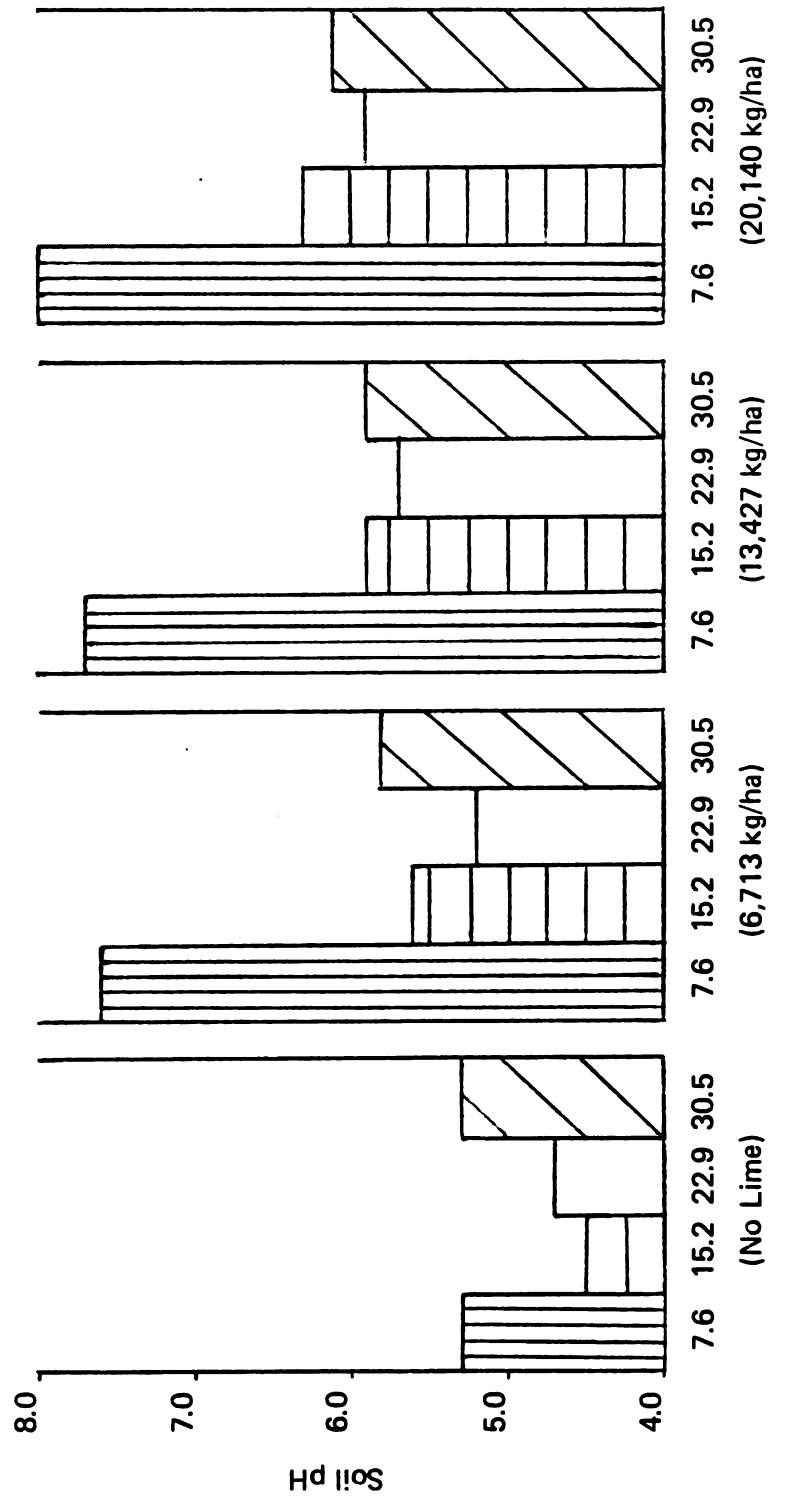

Figure 2. Influence of hydrated agricultural lime on asparagus soil pH Site–1

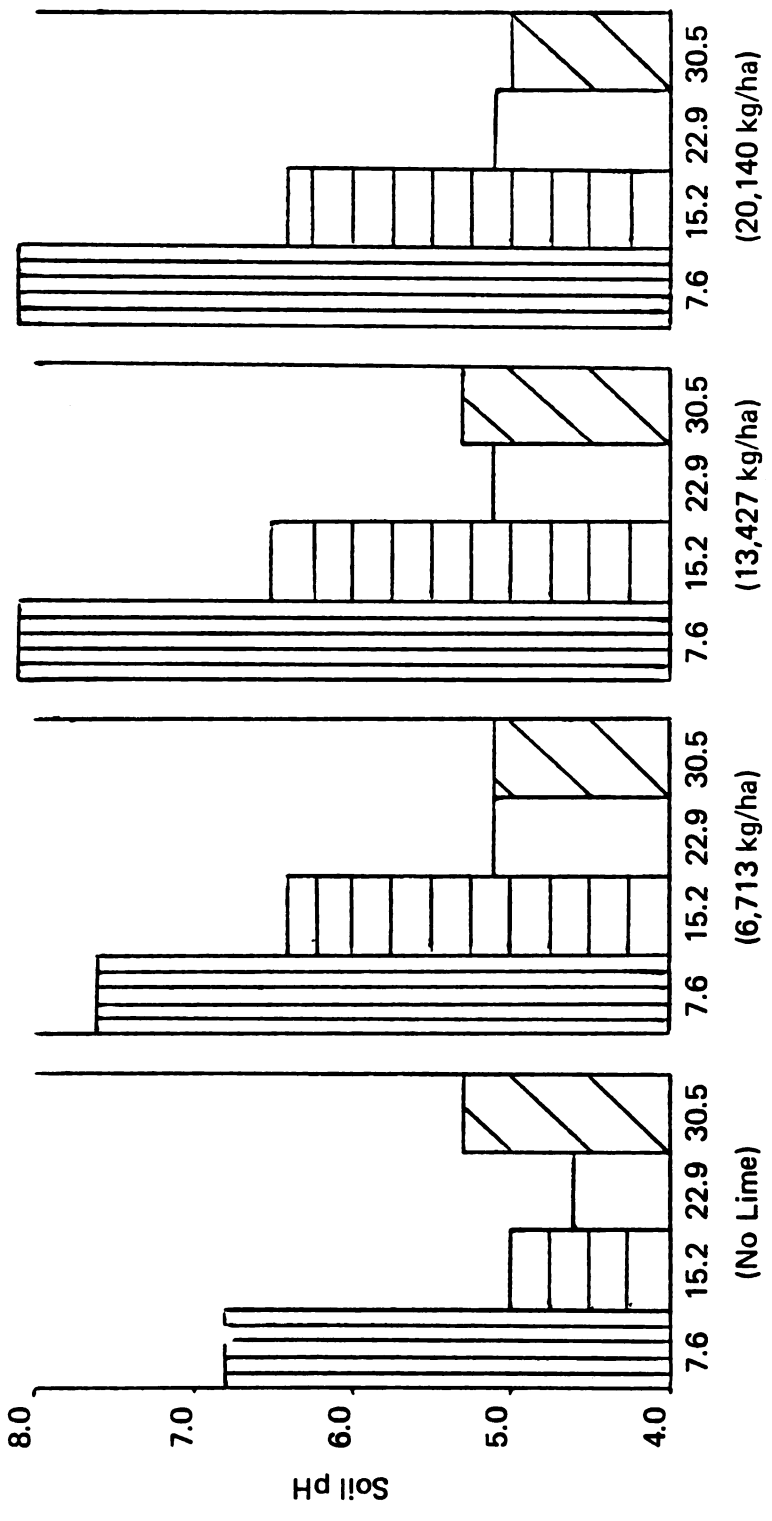

Figure 3. Influence of hydrated agricultural lime on asparagus soil pH Site–2

compared to the control. The lower two rates had a significant effect on soil pH only to the 22.9 cm depth.

At site #2, even with the grower applied lime, all rates of lime had significant effects on soil pH only to the 15.2 cm depth. This could have been due in part to the difference in soil type between site #1 and site #2 as well as the beginning soil pH.

II. Soil compaction - field study. At the rates of compaction utilized, there was a highly significant response in asparagus fern yield. (Table 5) At the lower compaction rate, growth was higher than that of the control, but at the higher compaction rate, growth was less than that of the control.

One reason for the increased yield with the lower compaction rate during the first growing season may have been better soil contact with the crown. The importance of seed to soil contact for optimum growth has been found in many other crops. (15)

The higher level of compaction exerted 4 times the total weight of the lower level. This additional compaction created a growth environment unsuitable for optimum growth as evidenced by the reduction in fern growth. It was calculated that the Ford exerted 4.1 psi with the rear tires and 11.5 psi with the front tires. The Cub exerted 2.3 psi with the rear tires and 4.0 psi with the front tires.

Based upon these findings, it appears that asparagus yields could be increased if growers were to utilize lighter

Table 5. Influence of soil compaction on asparagus growth

Compaction Tool and Weight	Total Fern Weight (g)
None	6.8
Cub (IH) Tractor Weight—682 kg	8.1
Ford 5000 Tractor Weight—2,727 kg	5.6

LSD .01=0.944

weight vehicles during the spraying and harvesting of the crop on new and subsequent plantings. Due to the possibility of increasing soil compaction, field moisture conditions should be considered. Although growers do not normally drive directly over asparagus rows it should be recognized that as asparagus crowns mature the rhizomes and root systems grow between the original rows. Therefore increasing the potential for damage as a result of soil compaction. It has been determined that no-till cultural practices will reduce soil compaction on asparagus, and that adequate herbicides are available to provide season long control of weeds without adversely effecting yields. (23 25 35) The age of current plantings will determine if a change in cultural practices can reverse the damage already sustained.

III. A. Influence of herbicides on young asparagus crowns in the greenhouse. At the rates studied on this Locke sandy loam, in which high leaching could be obtained, all chemicals caused a highly significant reduction in crown growth regardless of the level of treatment. As expected, the greater the amount of herbicide applied, the lesser the growth of the crown. (Figure 4) Some crowns were killed at higher herbicide dosages. This data indicated that four herbicides currently being utilized on asparagus all have the potential to damage young crowns. They could also damage older crowns if overdoses are applied.

In looking only at fern growth parameters, it would appear that the low simazine rates were selective. However,

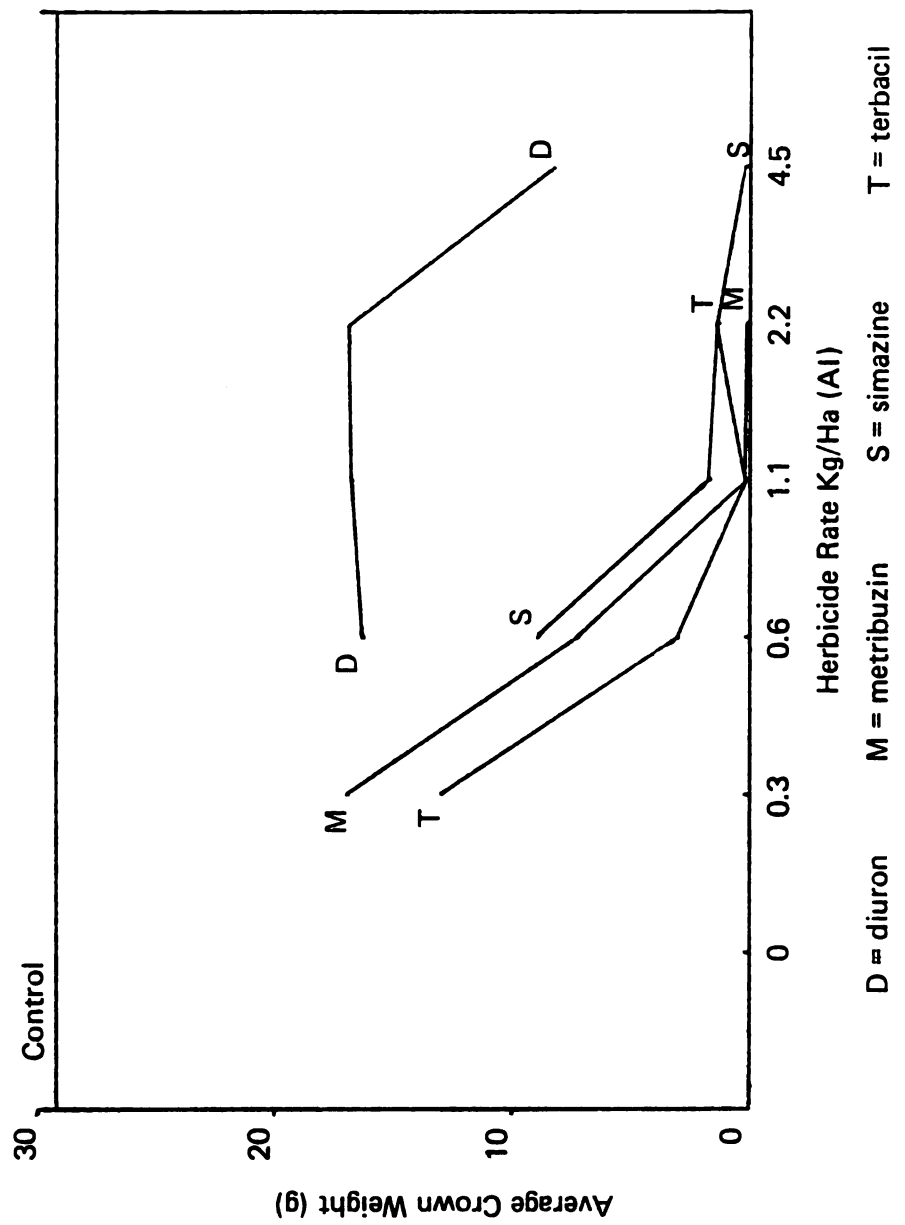

Figure 4. Effects of herbicides on growth of young asparagus crowns

when comparing crown growth as well as fern growth, diuron had the least affect on weight accumulation of the treated crowns. (Figure 5) Because asparagus plantings must last many years, herbicides need to be chosen that will not reduce crown growth early in their life.

Based upon this data, it appears the diuron is much safer than any of the other herbicides, even when leached to the crown. Metribuzin and terbacil each caused significant reductions in both fern and crown growth at rates higher than .3 and .6 kg/ha respectively.

III. B. Movement and persistence of soil applied herbicides in asparagus fields. Oats grown in soils from the 0 - 30.5 cm depth exhibited a significant increase in growth when planted into herbicide treated soil samples taken in April, 1979, as compared to the growth of oats planted into herbicide treated soil samples taken in June, 1978, and June, 1979. Oats grown in soil treated with simazine, diuron, and metribuzin grew significantly better in the soil samples taken in December, 1979, than in soil samples taken in June, 1979. The oats grown in soil samples treated with terbacil exhibited a steady decline in growth when planted into soil samples taken after April, 1979.

Simazine

Oats grown in the simazine treated soils (0 - 30.5 cm) did not grow as well as the control 12 and 18 months after the last herbicide application, regardless of the rate of herbicide utilized. This is an indication of simazine

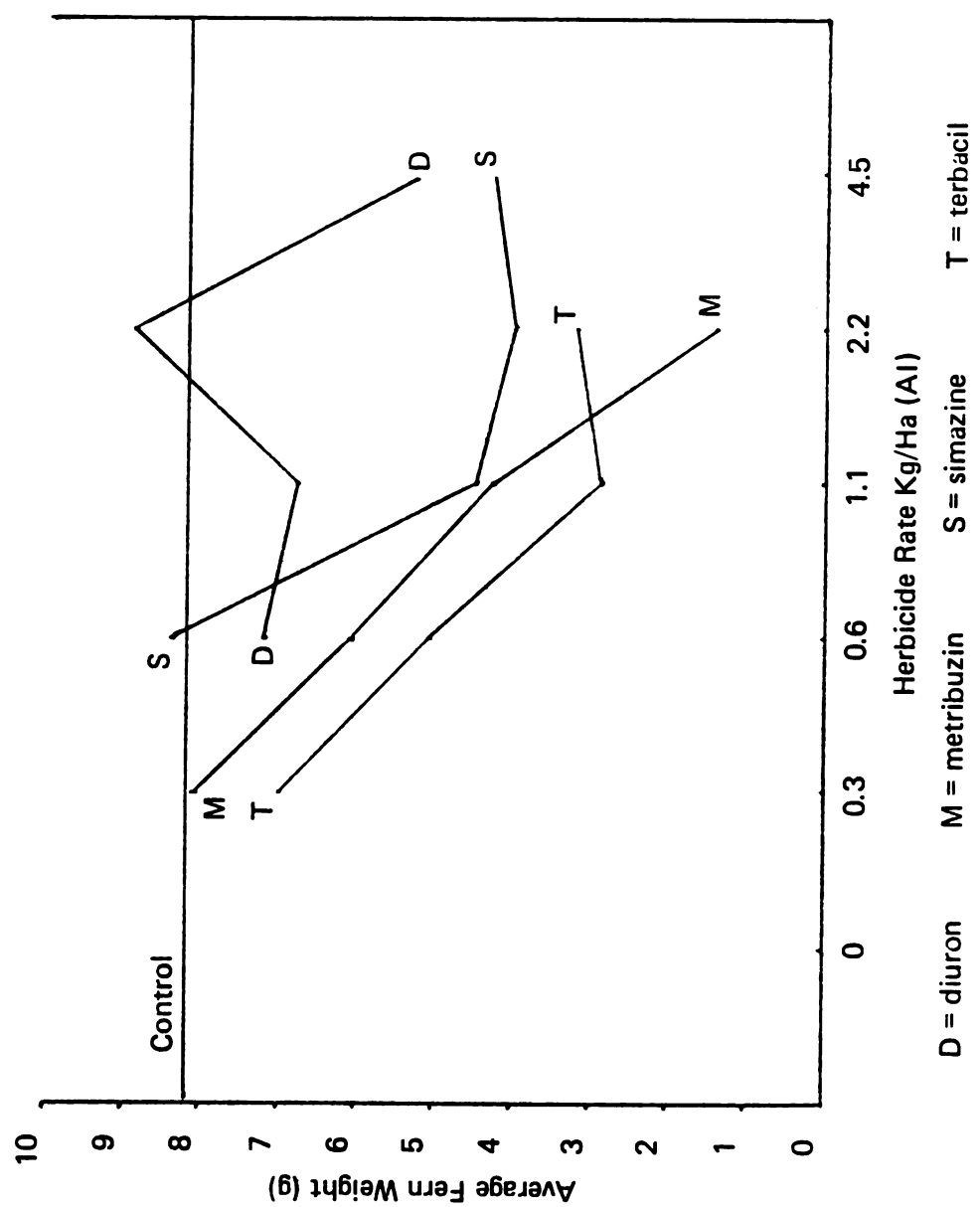

Figure 5. Effects of herbicides on growth of young asparagus fern

persistence in the soil, and lack of water solubility. (3 4) In treated soil samples from the 30.5 - 61 cm depth, at the rate of 2.2 kg/ha, there was an insignificant effect of the herbicide on the oats. This is consistent with previous findings. (24) Oats grown in treated soil samples 61 - 91.4 cm depth varied in their growth. Based upon previous research with simazine, (4 25 35) it is believed oat growth at this depth was not affected by the herbicide treatment. (Figures 6-11)

Diuron

Oats grown in the diuron treated soils at the 0 - 30.5 cm depth exhibited less injury than those grown in the simazine treated soils, but did not grow as well as the control at 12 and 18 months after treatment. At depths greater than 30.5 cm, within the time frame in question, and considering the solubility of diuron in the soil, the effect of diuron on oats was believed to be insignificant. (10 37) (Figures 6-11)

Metribuzin

Oat growth in the metribuzin treated soils at the 0 - 30.5 cm depth 12 months after treatment was considerably less than that of the control. However, at the 1.1 kg/ha rate, oats grown in metribuzin treated soils were equal tc the oats grown in the control in soil samples collected 18 months after treatment. At depths greater than 30.5 cm, the effect of metribuzin on oats is believed to be

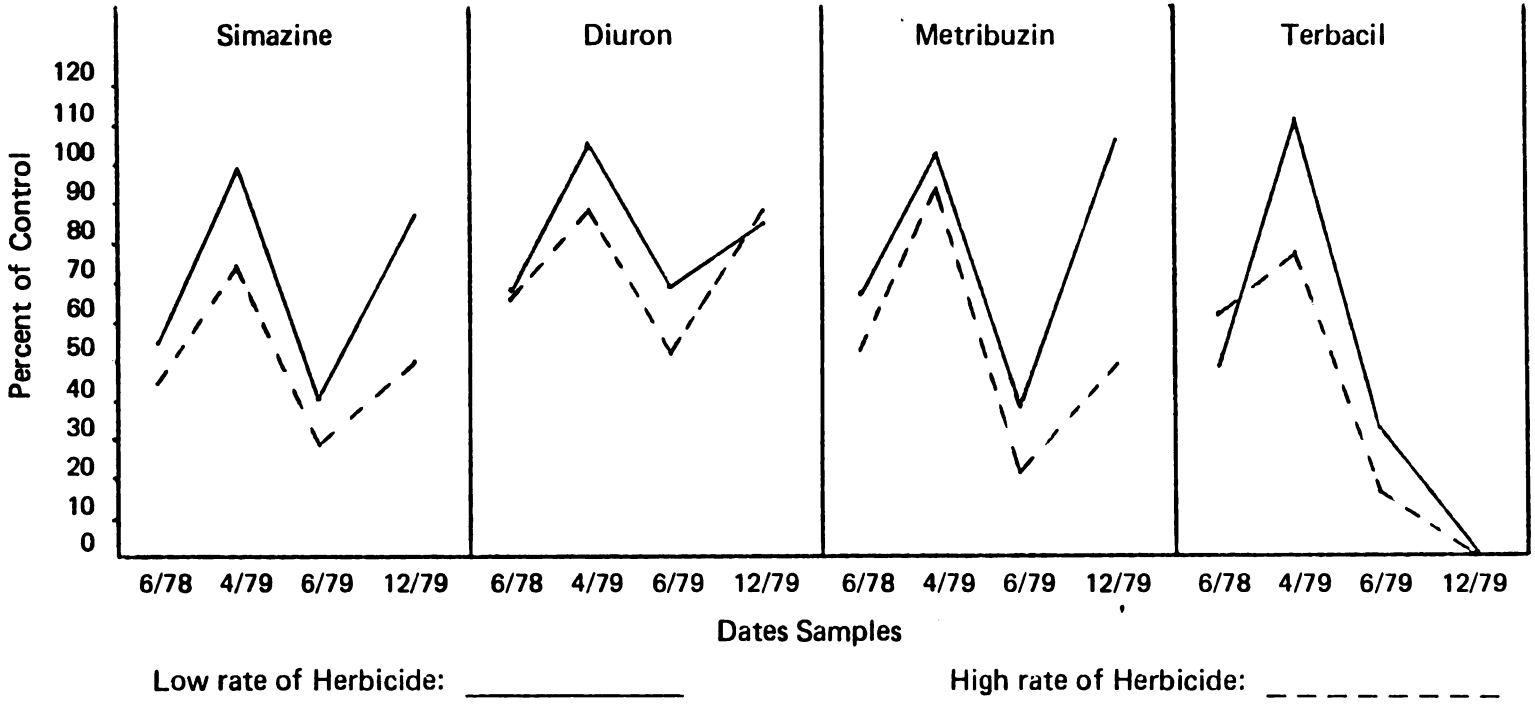

Figure 6. Investigation of factors which contribute to asparagus decline in Michigan, Location 1, 0 – 30.5 cm depth of soil sample

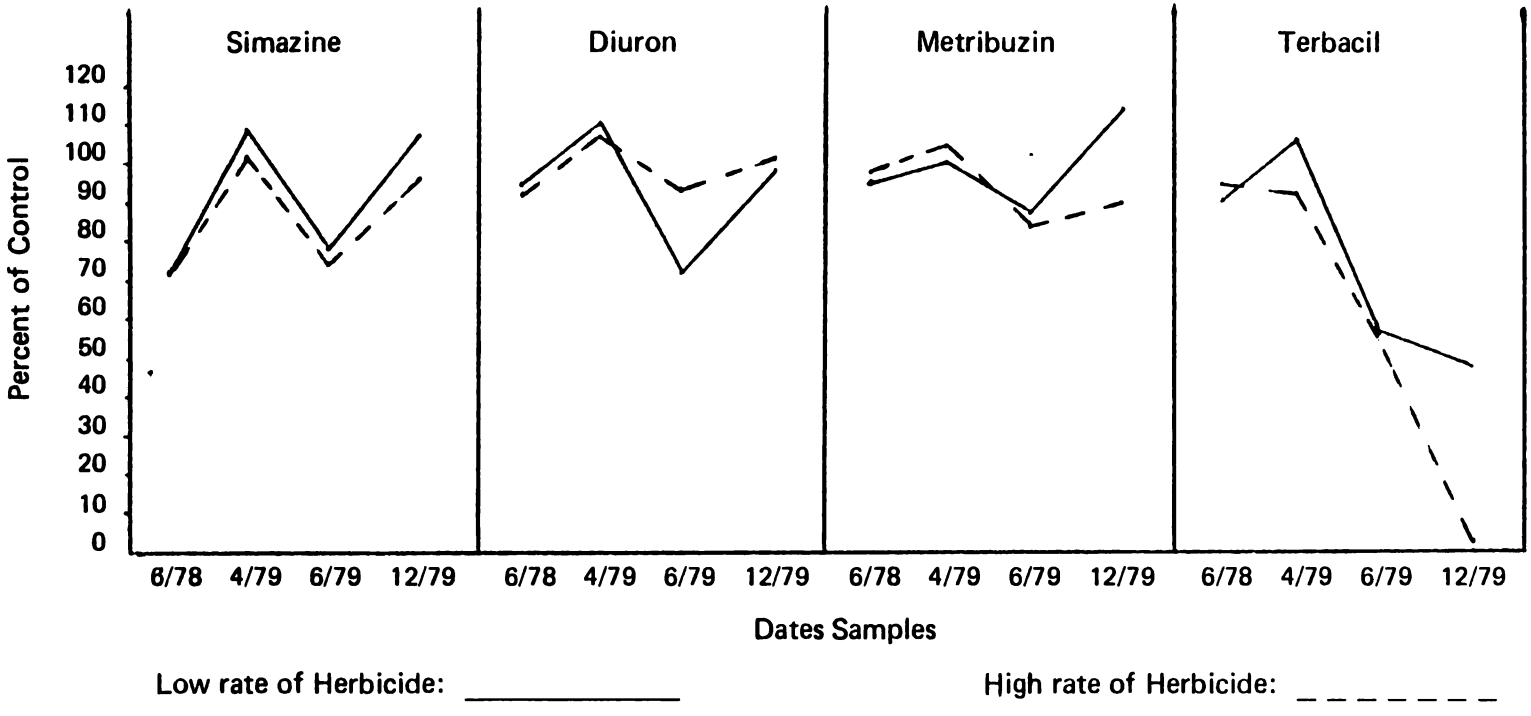

Figure 7. Investigation of factors which contribute to asparagus decline in Michigan, Location 1, 30.5 – 61 cm depth of soil sample

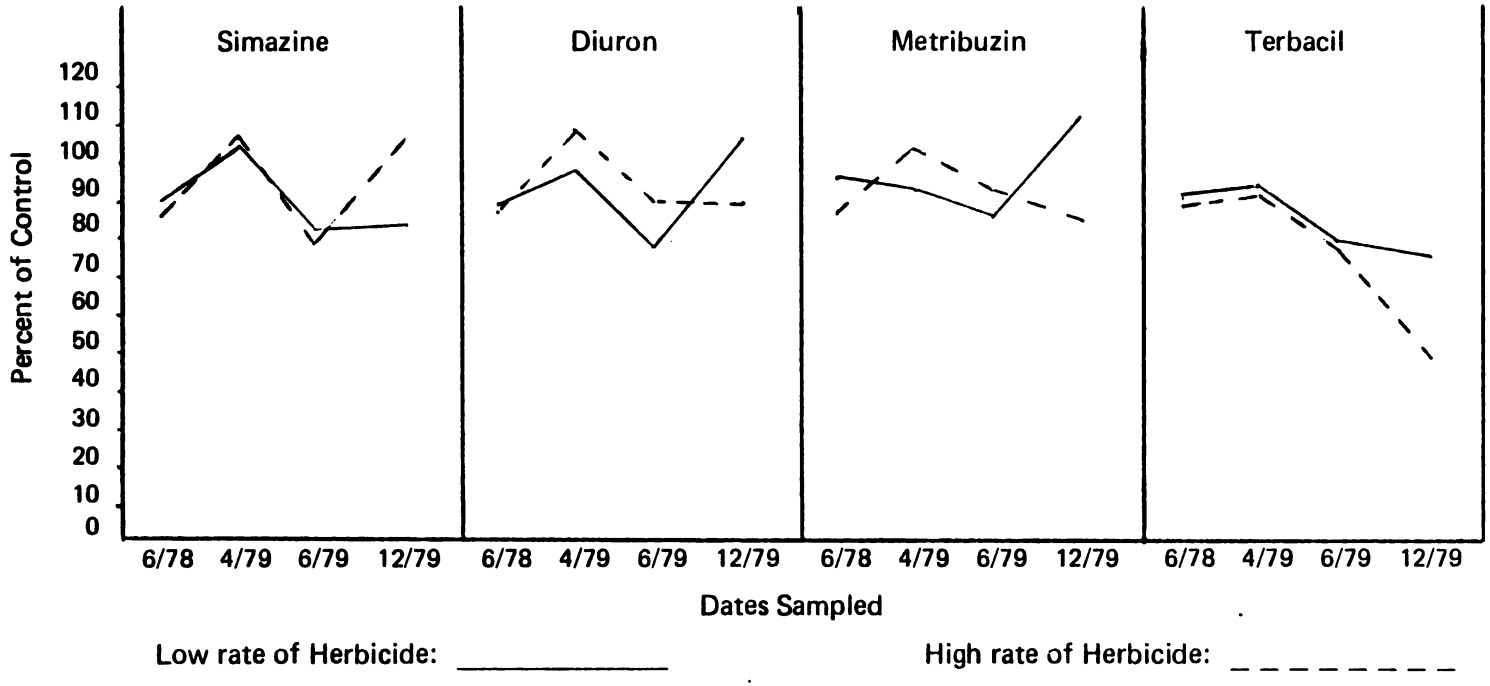

Figure 8. Investigation of factors which contribute to asparagus decline in Michigan, Location 1, 61 – 91.4 cm depth of soil sample

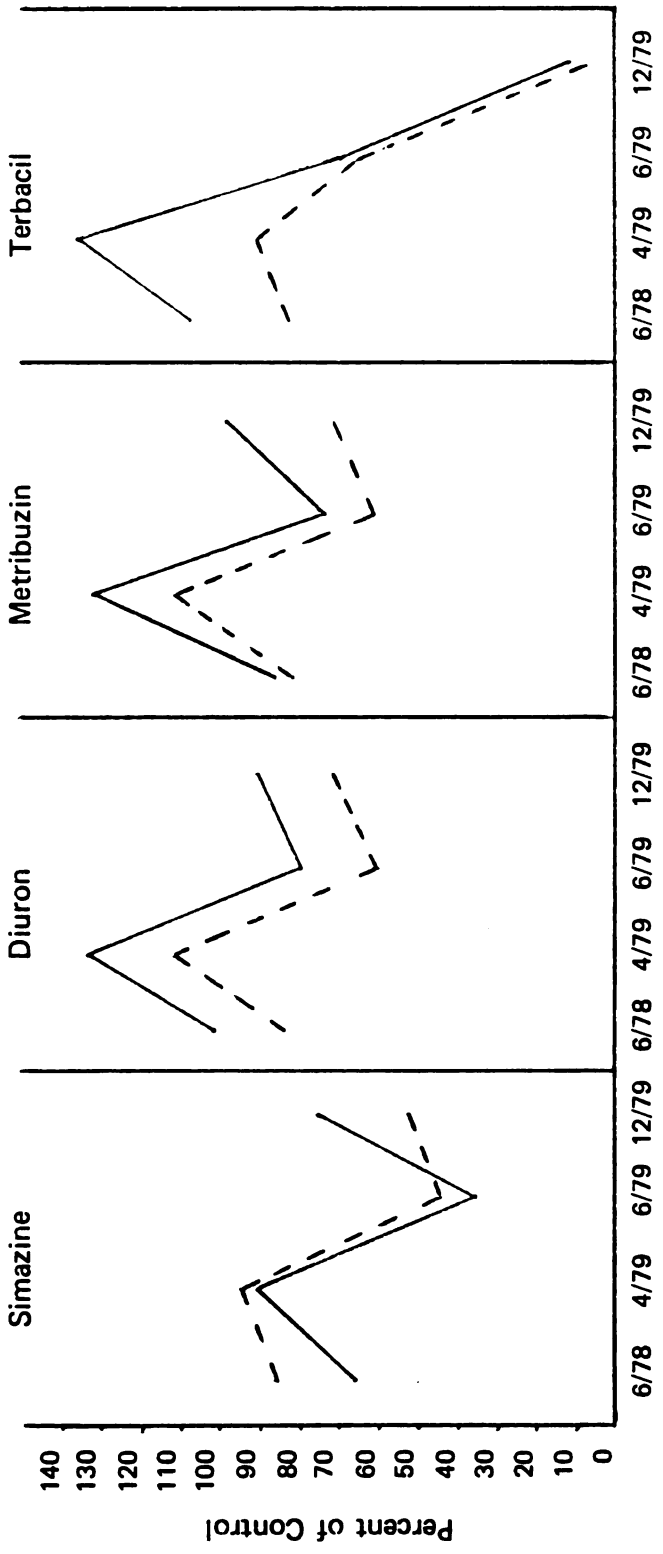

Figure 9. Investigation of factors which contribute to asparagus decline in Michigan, Location 2, 0 – 30.5 cm depth of soil sample

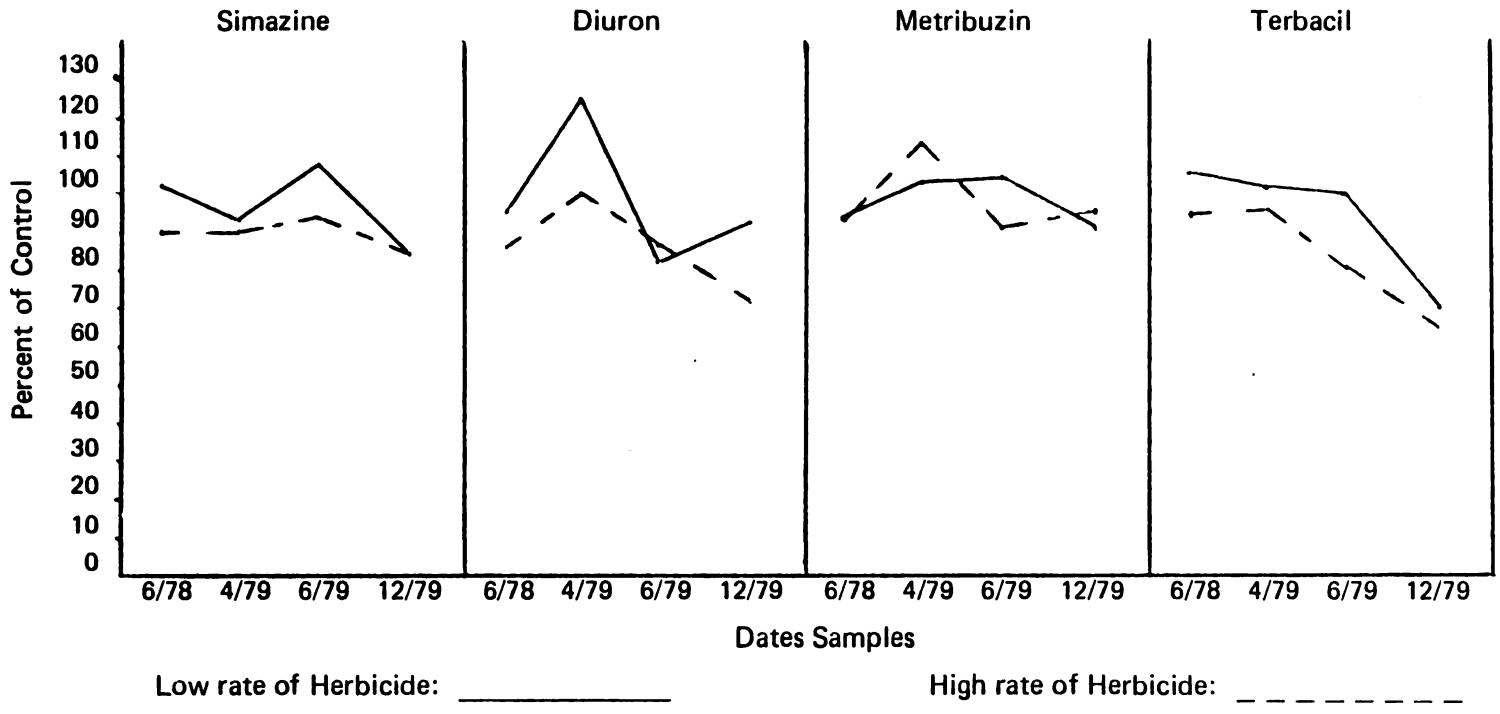

Figure 10. Investigation of factors which contribute to asparagus decline in Michigan, Location 2, 30.5 – 61 cm depth of soil sample

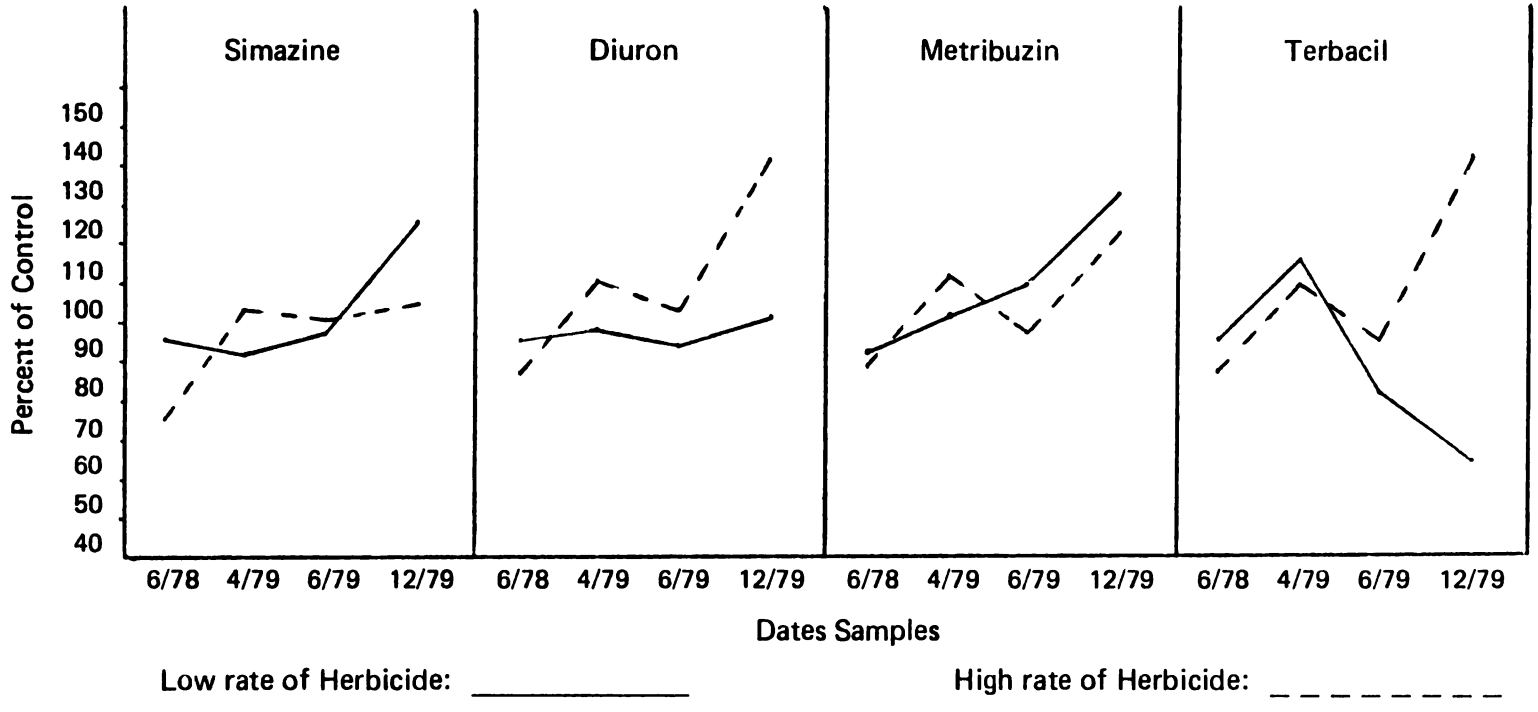

Figure 11. Investigation of factors which contribute to asparagus decline in Michigan, Location 2, 61 – 91.4 cm depth of soil sample

insignificant in part due to the soil type and soil pH. (14 26) (Figures 6-11)

Terbacil

Soil samples taken April, 1979, in the 0 - 30.5 cm depth at the 1.1 kg/ha rate caused a significant increase in oat growth above the control. In soil samples taken in June, 1979, and December, 1979, the oat growth was significantly lower than that of the control in soils of this depth. (35) At the soil sample depths of 30.5 - 91.4 cm, the presence of terbacil consistently reduced the growth of oats probably due to its leaching. (10 35) These studies indicate that terbacil poses the greatest threat for adverse impact on asparagus. (Figures 6-11)

IV. A. Effect of asparagus residues on young crowns in the greenhouse. The fern was harvested at 4 and/or 8 week intervals after which the fresh weights were determined. The results reported here are from 4 experiments. (Figures 12 13)

In the plantings with a 4 week harvest interval, and unleached root material added, 3 out of the 4 treatments exhibited a significant decrease in yield compared to the control group. In the 4 week harvest interval with leached root material added, all treatments exhibited a significant decrease in yield compared to the control group. This indicates that young asparagus crowns planted into soils containing either fresh or decaying asparagus root material

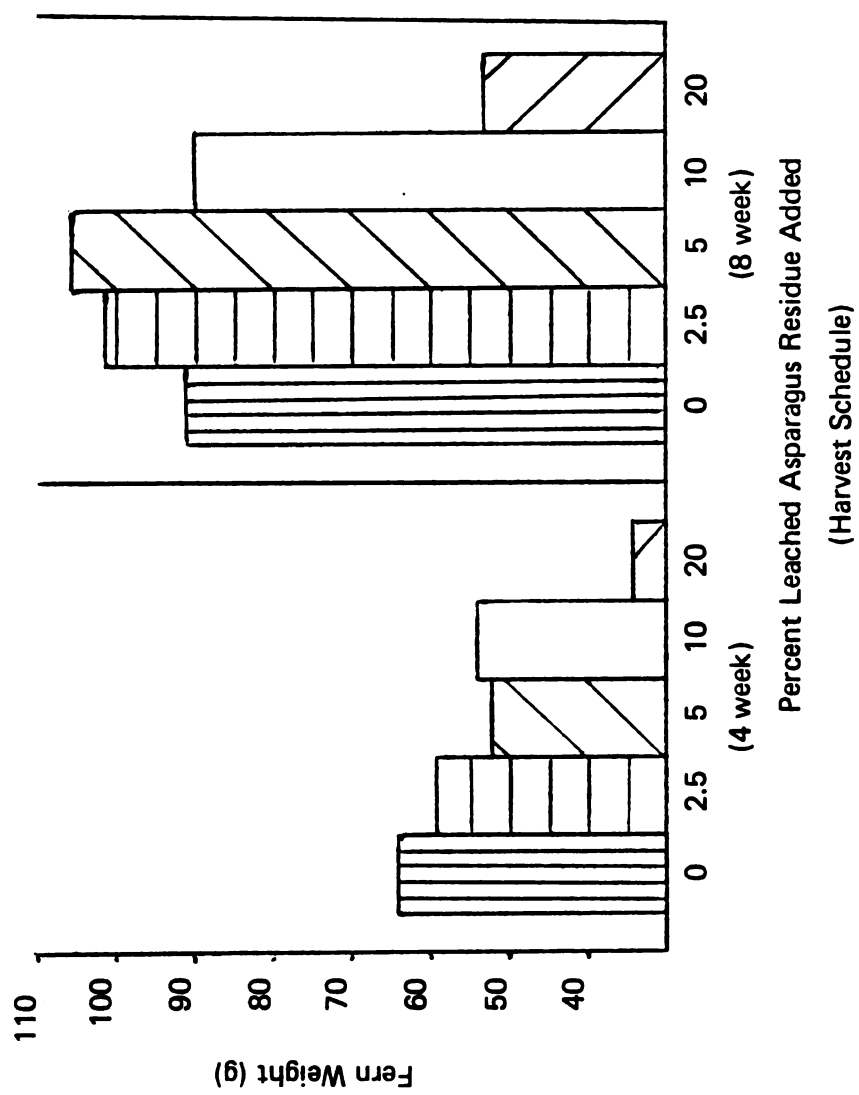

Figure 12. Effect of leached asparagus residue on fern growth of newly planted asparagus crowns

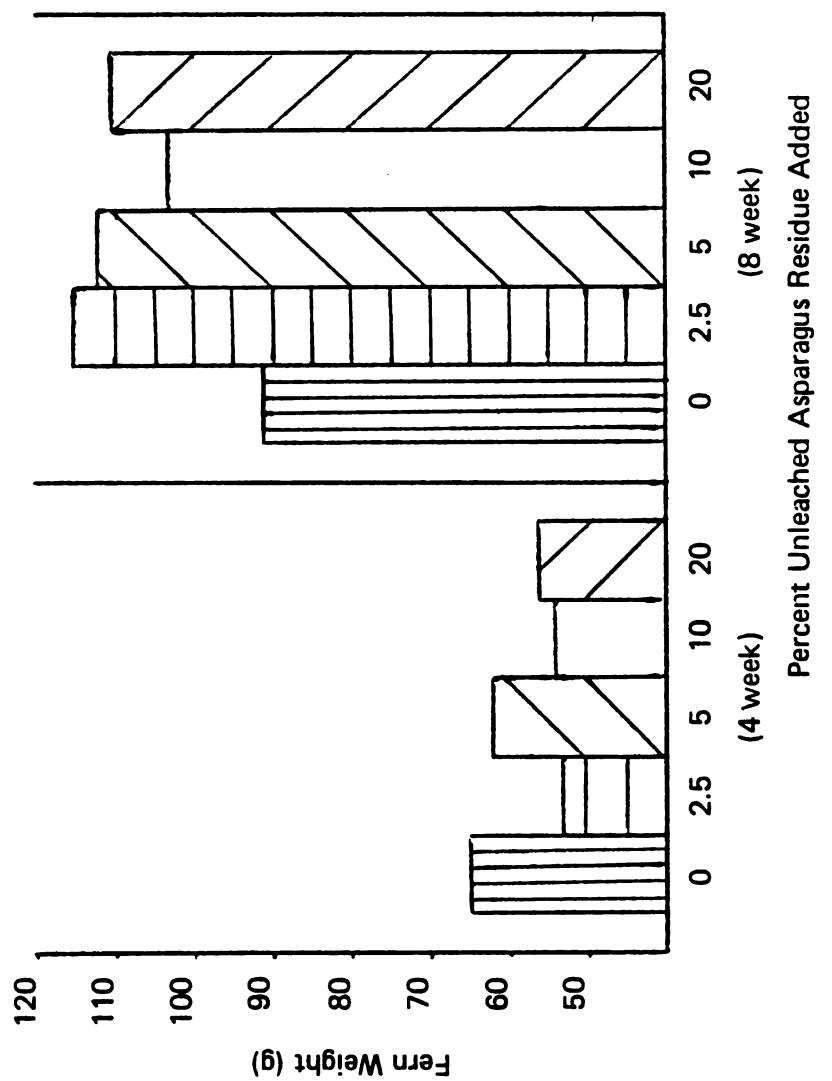

Figure 13. Effect of unleached asparagus residue on fern growth of newly planted asparagus crowns

in quantities as low as 2.5% by weight can suffer a reduction in yield if growth is interrupted on a 4 week basis.

Those treatments with only one harvest in 8 weeks exhibited both increases and reductions in yield. All treatments receiving unleached root material displayed a significant increase in growth over the control treatment. In addition, the two lowest rates of leached root material produced a significant increase in yield over the control.

This behavior indicates that over a longer period of time (8 weeks) the young asparagus crown can respond positively to the ground asparagus root material. (16 17) This may indicate a decomposition of inhibitors or reduction in levels to stimulating concentrations.

The reduced yields at the 4 week harvest interval could be caused by the additional stress placed upon the young crown by the frequent cutting as well as toxins given off from or during decomposition of the asparagus root material. (22)

This evidence indicated that toxins given off by decomposing asparagus root material are relatively short lived. Therefore, long term allelopathy effects should not be encountered unless established plants continue to release toxins. Long term replant problems should not necessarily be due to the presence of decaying asparagus root material in the soil, but may be caused by other factors such as Fusarium root rot.

Another consideration is the carbon:nitrogen ratic. While a normal C:N ratio is 10:1, when organic materials with a C:N ratio of greater than 30 are added to soils, there is immobilization of soil nitrogen during the initial decomposition process. The time required for this decomposition cycle to run its course depends upon the quantity of organic matter added, the supply of utilizable nitrogen, the resistence of the material to microbial attack (a function of the amount of lignins, waxes, and fats present), and temperature and moisture levels in the soil. (31)

Other factors which could have an effect on plant growth or the toxins being emitted are: microorganisms present in the soil, soil type, texture, per cent organic matter content, soil water holding capacity, cation exchange capacity, as well as the nutrient levels in the soil.

IV. B. Effect of asparagus residues on young asparagus crowns - field study. Fern harvested 7 months after planting indicated that asparagus root residues can decrease growth when placed in the root zone of young crowns. Plants which received 4 kg of shredded asparagus root material per 6.1 m of row yielded less fern than did the controls or the plants that received 2 kg/6.1 m. This would indicate that under these soil and growing conditions that 4,000 kg/ha or more of asparagus root material can adversely affect the growth of young asparagus crowns thus possibly affecting both long term yields and longevity of an asparagus planting. (15) This is well below the amount

of residue that might be left when a field is plowed out. These results confirm those obtained when growing young asparagus crowns under similar treatment conditions in greenhouse experiments. (15) It appears that the asparagus plant at various stages of decay may release chemicals which are toxic to young asparagus crowns. (Table 6) Or as indicated previously, the interaction of released toxins with microorganisms, variations in soil type characteristics and/or variations in nutrient levels could possibly be affecting asparagus growth.

Table 6. Influence of asparagus residue on growth of young asparagus crowns

Asparagus Root Residue (kg/6.1m)	Fern Weight (kg)
0	3.0
2	2.9
4	2.7
LSD at .01	0.2

LITERATURE CITED

LITERATURE CITED

1. Barber, S.A., R.W. Pearson, and F. Adams. 1967. Liming materials and practices. Eds in Soil acidity and liming. (Agronomy, 12:125-160) (Madison, WI: Am. Soc. of Agronomy, 1967).

2. Bertrand, A.R., and H. Kohnke. 1957. Subsoil conditions and their effects on oxygen supply and the growth of corn roots. Soil Sci. Soc. Am. Proc. 21:135.

3. Burnside, O.C., C.R. Fenster, and G.A. Wicks. 1963. Dissipation and leaching of monuron, simazine, and atrazine in Nebraska soils. Weeds 11:209-213.

4. _____, E.L. Schmidt, and R. Behrens. 1961. Dissipation of simazine from the soil. Weeds 9:477-484.

5. Christenson, D.R., and E.C. Doll. 1973. MSU Bull. E-471. Lime for Michigan soils. E. Lansing, MI.

6. Collins, J.B., E.P. Whitside, and C.E. Cress. 1970. Seasonal variability of pH and lime requirements in several southern Michigan soils when measured in different ways. Soil Sci. Soc. Am. Proc. 34:56-61.

7. Deonier, M.T. and G.P. Hoffman. 1944. Asparagus production in the lower south with special reference to time and length of cutting season. Am. Soc. Hort. Sci. Proc. 45:413-417.

8. Gamble, S.J., and A.L. Kenworthy. 1961. Soil pH in relation to different liming materials applied to an apple and a peach orchard. Mich. Ag. Exp. Bull. 43(4): 695-699.

9. Hartung, A. 1983. Effects of allelopathic substances produced by asparagus on the incidence and severity of Fusarium root rot. Thesis for the M.S. Degree. Michigan State University. 62.

10. Herbicide Handbook, WSSA.

11. Hoffer, G.N. 1947. Soil aeration and crop response to fertilizer. Better crops with plant food magazine.

12. Jørgensen, M.B., and A. Henriksen. 1954. Forsøg med forskellig jordreaktion til asparages og rabarber. (The effect of soil reaction on asparagus and rhubarb.) Tidsski. Planteavl 57:690-700.

13. Kitahara, Y., H. Yanagawa, T. Kato, and N. Takahashi. 1972. Asparagus acid, a new plant growth inhibitor in etiolated young asparagus shoots. Plant and Cell Physiol. 13(5):923-925.

14. Ladlie, J.S., W.F. Meggit, and D. Penner. 1976. Role of metribuzin dissipation in field soils. Weed Sci. 24(5):508-511.

15. Laufer, G.A. and S.A. Garrison. 1977. The effect of asparagus tissue on seed germination and asparagus seedling growth: Possible allelopathic interactions. Hort. Sci. 12(2):385.

16. Lewis, E.P. 1934. Asparagus yields as affected by severity of cutting. Ill. Agr. Exp. Sta. Bull. 401: 26-36.

17. Lloyd, J.W., and J.P. McCullem. 1938. Yields of asparagus as affected by severe cutting of young plantation. Ill. Agr. Exp. Sta. Bull. 448:159-172.

18. Majka, J.T., and T.L. Lauy. 1977. Adsorption, mobility and degradation of cyanazine and diuron in soils. Weed Sci. 25(5):401-406.

19. Michigan Agricultural Reporting Service. 1972-1980. Michigan Agricultural Statistics. Mich. Dep. of Agr. Lansing, MI.

20. Olymbios, C.M., and W.C. Schwabe. 1977. Effects of aeration and soil compaction on growth of carrots. J. Hortic. Sci. 52(4):485-500.

21. Phillips, R.E., and D. Kirkham. 1962. Soil compaction in the field and corn growth. Agron. J. 54:29-34.

22. Putnam, A.R., and W.B. Duke. 1978. Allelopathy in agroecosystems. Ann. Rev. Phytopathol. 16:431-451.

23. _____, and M.L. Lacy. 1977. Asparagus management with no-tillage. MSU Ag. Exp. Sta. Rpt. 39. E. Lansing, MI.

24. Raghauan, G.S., V.E. McKyes, and M. Chasse. 1971. Effect of wheel slippage on compaction. J. Agric. Res. 22(1):79-83.

25. Sandhu, S.S., and J.K. Greig. 1966. Effects of herbicides on asparagus and weeds and residues retained in the soil. Proc. Am. Soc. Hort. Sci. 88:372-377.

26. Savage, K.E. 1977. Metribuzin persistence in soil. Weed Sci. 25(1):55-59.

27. Smucker, A.J., et al. 1979. 1979 Research Report, Saginaw Valley Bean-Beet Research Farm and Related Bean-Beet Research. 61-79.

28. Stout, B.A., W.F. Buchele, and F.W. Snyder. 1961. Effect of soil compaction on seedling emergence under simulated field conditions. J. of ASAE. 42:68-71

29. _____, F.W. Snyder, and W.M. Carleton. 1956. The effect of soil moisture and compaction on sugar beet emergence. J. of A.S.S.B.T. 9:277-283.

30. Takatori, F.H. J.I. Stillman, and F.D. Souther. 1970. Asparagus yields and plant vigor as influenced by time and duration of cutting. Cal. Apr. 24:9-11.

31. Tisdale, S.L., and W.L. Nelson. Soil Fertility and Fertilizers, 3rd ed. New York:Macmillan, 1975.

32. Troug, E. 1947. The liming of soils. Yearbook of Agriculture, 1943-1947. 566-576.

33. U.S. Department of Commerce, Weather Bureau. 1972 thru 1981. Climatological Data, Michigan.

34. Upchurch, R.P., F.L. Selman, D.D. Mason, and E.G. Kamprath. 1969. Weeds 14:42.

35. Welker, W.V., and J.L. Brogdon. 1972. Effects of continued use of herbicides in asparagus plantings. Weed Sci. 20(5):428-432.

36. Williams, J.B., and J.M. Garthwaite. 1973. The effects of seed and crown size and length of cutting period on the yield and quality of asparagus grown on ridges. Exp. Hort. 25:77-86.

37. Wolf, D.E., R.S. Johnson, G.D. Hill, and R.W. Varner. 1958. Proceedings of the North Central Weed Conference. 15:7.