AN ABSTRACT OF THE THESIS OF

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(Name) (Degree)

in HORTICULTURE presented on March 16, 1970
(Major) (Date)

Title: THE PERFORMANCE OF N-(1,1-DIMETHYLPROPYNYL)-3,5-DICHLOROBENZAMIDE AND OTHER HERBICIDES IN CONTROLLING WEEDS IN LETTUCE AS AFFECTED BY SOIL TYPE AND WEATHER CONDITIONS

Abstract approved: [signature]
Dr. Garvin Crabtree

Chemicals are being sought that can control weeds in lettuce under different environmental conditions, soil types and weed populations. The extensive or repeated use of a herbicide may lead to important changes in the weed population which call for new materials that can take care of the modified situation.

In the search for new chemicals, RH 315[1] has appeared promising in some respects.

Greenhouse and field experiments were conducted to determine the tolerance of lettuce (crisphead type) to RH 315 in three types of soil. Its performance on weeds under different environmental

[1] Trade name is Kerb. Chemical name is N-(1,1-dimethylpropynyl)-3,5-dichlorobenzamide.

conditions, its residual action on other vegetables, as well as pre- and postemergence activity on weeds were also tested. Other herbicides were used in some experiments.

Lettuce of the crisphead type proved to possess high tolerance to RH 315. The tolerance was greater in a silty clay loam and a muck soil than in a sandy soil. In all types of soil, the safety factor was greater than 2 X when susceptible weeds are considered. The degree of tolerance varied with the season in field experiments.

RH 315 at 1.5 to 2 lb/A in a silty clay loam and at 1 to 1.5 lb/A in a sandy loam provided excellent control of annual bluegrass, Italian ryegrass, barnyardgrass, green foxtail, common chickweed, purslane, mouseear chickweed, lambsquarters, henbit, red deadnettle, shepherspurse and bittercress. The control of pigweed and wild mustard required higher rates. No control of composite species was achieved with this compound.

Delaying sprinkler irrigation after application caused reduction in RH 315 activity. It was more effective in controlling weeds in early fall than during the summer.

Two months after application, RH 315 residues from rates which were effective in controlling susceptible weeds did not cause injury to bush beans, sweet corn, cucumbers, red beets, common chickweed and annual bluegrass, under summer conditions.

When applied at the stage of two true leaves or before, under conditions of early fall, RH 315 proved to possess postemergence activity on weed species that are controlled by preemergence applications of this compound. From 17 to 20 days were required for RH 315 to exert its effect in postemergence application.

Trifluralin at 0.75 lb/A provided excellent control of Italian ryegrass, barnyardgrass, pigweed and purslane both in a silty clay loam and a sandy loam. Benefin and EL 179 both at 1 lb/A gave good control of the same weeds in the silty clay loam, but their performance was inferior to that of trifluralin. Benefin at 0.75 lb/A did not perform very well in the sandy loam.

Delaying incorporation 68 hours after the herbicide application caused 70% loss of trifluralin activity and 35% loss of benefin action in a sandy loam soil. The residual action of trifluralin was greater than that of EL 179 and benefin when tested by vegetable plant growth 82 days after application. The least residual action was obtained with RH 315 and CDEC when tested 60 days after application.

Bensulide at 6 lb/A performed poorly in a silty clay loam, whereas CDEC at 5 lb/A provided good control of pigweed, Italian ryegrass and barnyardgrass in the same type of soil.

The results obtained in this research showed that RH 315 is effective for selective control of some weeds in lettuce that are not controlled by standard herbicides. Furthermore, its biological residual life is sufficiently long to provide weed control for an entire crop cycle but not long enough to cause injury to succeeding, susceptible vegetable crops. The disadvantages of RH 315 are its poor activity on pigweed and its dependence on the supply of moisture immediately after application under summer conditions.

The Performance of N-(1, 1-dimethylpropynyl)-3, 5-dichlorobenzamide and Other Herbicides in Controlling Weeds in Lettuce as Affected by Soil Type and Weather Conditions

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1970

APPROVED:

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Date thesis is presented March 16, 1970

Typed by Donna L. Olson for Agustin Mitidieri

ACKNOWLEDGEMENT

I owe a debt of gratitude to Dr. Garvin Crabtree, who accepted me as a graduate student, for his generous assistance, guidance and advice throughout my graduate program as well as for his helpful suggestions in the completion of this manuscript.

Sincere appreciation is extended to Dr. Harry J. Mack and Dr. Robert L. Powelson for their critical reading and suggestions concerning the preparation of this manuscript, and for serving on my graduate advisory committee.

I wish to express my gratitude to the Department of Horticulture for the use of their facilities, for advice and help in the course of this graduate program, and particularly to the Vegetable Research Farm staff for their help in conducting the field research reported in this thesis.

I wish to thank Mrs. Georgena Knapp for her helpful review and corrections of this manuscript.

My thanks to the Agency for International Development, Department of State, and to the Instituto Nacional de Technologia Agropecuaria, Argentina, for financial assistance in this graduate program.

I especially want to thank my wife, Irma, and my daughter, Mariel, for their patience and forbearance during the period of schooling.

Finally, I am deeply grateful to my parents for their sacrifice and encouragement through many years of school.

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INTRODUCTION

Lettuce is one of the most important vegetable crops in the United States. Most of the acreage devoted to this crop is located in the western states, with California and Arizona together accounting for over 80% of the total (U.S.D.A., 1969, p. 179).

Weed competition causes great loss to lettuce crops through reduction of production and quality. The estimated average annual loss to lettuce due to weeds in the United States for the period 1951-60 was a little over 10 million dollars (U.S.D.A., A.R.S., 1965). The same source also reported that the cost of weed control in lettuce was about 20 million dollars per year. Without some weed control the loss would be nearly 100 percent.

According to Agamalian *et al.* (1967), weeding the seed row by hand-hoeing costs approximately $20 to $60 per acre. To that expense is added the cost of mechanical cultivation for controlling weeds in the furrow and between rows of the bed. In Argentina[1], where the total area is broadcast-seeded, the cost of hand-weeding lettuce is estimated to be about $20 to $45 per acre.

The principal weeds found in lettuce in California are reported in Appendix I (Agamalian et al., 1967); those found in Argentina[1], in Appendix II; and in Oregon, in Appendix III[2].

The economic importance of the weed problem in lettuce has three main aspects, (a) the losses caused by weed competition; (b) the cost of controlling these weeds; and (c) the need for a thorough chemical weed control, since the more successful mechanical lettuce thinners do not distinguish between weeds and lettuce seedlings (Agamalian et al., 1967).

As stated before, weed control in lettuce is necessary otherwise the entire crop may be lost. The need for selective herbicides stems from the fact that the increasing cost and scarcity of field labor have made hand-weeding too expensive and sometimes impossible. Chemical weed control cannot rely upon a single selective herbicide for the following reasons: (1) the extensive and repeated use of what was once a good herbicide may lead to important changes

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[1] Survey carried out by the author during 1965-67, at the Estacion Experimental de San Pedro, I.N.T.A. San Pedro (B), Argentina.

[2] Parsons, Jack. Extension Agent, Oregon State University. Personal communication. Oregon City, Oregon. February 12, 1970.

in the weed population which call for new materials than can take care of the modified situation; (2) the practice of chemical weed control in lettuce is bringing about the increase of weed populations which are not controlled by standard herbicides used in this crop. Therefore, new chemicals are being sought that can improve the situation.

A new herbicide N-(1, 1-dimethylpropynyl)-3, 5-dichlorobenzamide (RH 315)[3], has appeared promising in some respects. It is effective in controlling many crucifers and other weed species that are not controlled by standard herbicides used in lettuce.

The primary objective of this research was to determine the tolerance of lettuce to RH 315 in three soil types in greenhouse studies and two soils under field conditions. The performance on volunteer weeds as well as on species seeded for this purpose was evaluated. The effect on certain rotation crops was also assessed. Other herbicides were tested in some experiments.

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[3] Experimental herbicide from Rohm and Haas Company, Independence Mall West, Philadelphia, Pennsylvania 19105.

LITERATURE REVIEW

The earliest reference found on chemical weed control in lettuce suggested the use of isopropyl m-chlorocarbanilate (chlorpropham) at the rate of 1 to 3 lb/A (Shaw et al., 1956). Alban (1957) reported promising results with the same chemical when it was applied before crop emergence. The first two herbicides that were recommended (Ashton, 1959; Agamalian, 1962) with some success for weed control in lettuce were 2-chloroallyl diethyldithiocarbamate (CDEC) and isopropyl carbanilate (propham). They pointed out that CDEC gave only a narrow margin of safety and a poor control of purslane. In earlier tests McCarty et al. (1958) found no breaking point between low and high rates of CDEC. Complete control was not obtained even at the high rate of 10 lb/A. McCarty also showed that the order of tolerance of lettuce types to CDEC decreased as follows: red leaf, salad bowl, romaine and butterhead.

In Europe, the most widely recommended herbicide for weed control in lettuce has been chlorpropham (Staalduine, 1959; Woodford, 1960; Woodford and Evans, 1965). The last mentioned authors gave a list of weeds either susceptible or resistant to chlorpropham. They pointed out that watering after application should be avoided; otherwise, injury to lettuce may result when sunny periods lead to high temperatures. Webster (1961) had observed the same effect when the application of this compound was followed by heavy rains.

Woodford and Evans (1963), and Wall (1966) stated that chlorpropham should not be used on very light, sandy or silty soils, as injury may result. Lachman and Michelson (1960) reported that chlorpropham at 2 to 4 lb/A was not very effective in controlling weeds in lettuce, whereas CDEC at 4 to 8 lb/A gave excellent weed control and increased yields. Good results were achieved by using a mixture of CDEC and chlorpropham.

These discrepant and (or) inconsistent results reached a turning point about 1965. Previously Collins (1963) had noted that CDEC had not been good enough to establish its use in California. However, he remarked that a degree of weed control is definitely better than no weed control because partial weed control by the use of herbicides greatly reduces hand-weeding cost. New herbicides appeared in 1965. Ford (1965) reported promising results with N-butyl-N-ethyl-α, α, α-trifluoro-2, 6-dinitro-p-toluidine (benefin). He also found that α, α, α-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine (trifluralin), a closely related compound, exhibited less selectivity than benefin.

Lyons (1967) reported that in 1964 less than 2, 000 acres of lettuce were treated with herbicide in California; in 1965, about 5, 000 acres; and in 1966, 25, 000 acres. This rapid increase was due to more effective herbicides, along with a requirement for precision planting and mechanical thinning.

Agamalian et al. (1967) reviewed the results of several trials carried out with CDEC, chlorpropham, propham, benefin, 0,0-diisopropyl phosphorodithioate S-esther with N-(2-mercaptoethyl) benzenesulfonamide (bensulide) and dimethyl tetrachloroterephthalate (DCPA). They concluded that bensulide showed the greatest selectivity followed by propham and benefin. Chlorpropham and DCPA offer only a narrow margin of safety and results with CDEC have been inconsistent.

Romanowski et al. (1967) from experiments carried out in Hawaii, concluded that "... CDEC should still be considered as the standard herbicide for use in this area." They also added: "As in past experiments, bensulide and benefin will not control weeds on the Waimea loam at the FDA registered rates." Their results showed that several herbicides that perform satisfactorily in the continental United States do not meet commercial standards under the edaphic conditions of the Waimea loam which is a finely textured soil and has an organic matter content of 8%. Trifluralin was not phytotoxic on soils with high organic matter (8%), but it severely injured lettuce on Manoa silty clay loam soils with 2% organic matter content.

Menges and Hubbard (1965) reported that trifluralin was outstanding at 0.75 lb/A for selective weed control in lettuce. In a later paper, Menges and Hubbard (1967) reported the performance of several herbicides under conditions of stress: heavy rainfall and cold soil with short periods of flooding. Under such conditions benefin was more selective than trifluralin. According to Manca (1967), trifluralin is recommended in Italy for use on cabbage, cauliflower, lettuce and carrots at 0.4 to 0.8 lb/A applied preplant and immediately incorporated.

The most popular herbicide used recently for weed control in lettuce has been benefin, alone or in combination with propham. Other chemicals such as CDEC and DCPA have attained success in some areas. Even though these herbicides have been an important tool, complete solution of the weed problem has not been achieved in many cases, and in others the decrease of some noxious weed problems has paralleled the increase of new ones.

The challenge of this situation can be faced in different ways: the chemical approach, rotation or management practices. Industry is continuously synthesizing new compounds among which some may be found to improve the situation.

Along this line, a new herbicide has appeared which has proved to be promising for weed control in lettuce (O.S.U., 1968). This chemical, coded RH 315, has performed better on grasses than on broadleaf species. Also, better results were attained in preemergence treatment than in preplant soil incorporated application. At the rate of 3 lb/A it completely controlled ryegrass, orchardgrass, barnyardgrass, cheatgrass, green foxtail, wild loats, pigweed, purslane, and, almost completely, wild mustard and lambsquarters. Agamalian and Lange (1969) reported that RH 315 in their trials gave excellent control of shepherdspurse, burning nettle, hairy nightshade and common purslane, in preemergence treatments. They also confirmed that RH315 is less effective in preplant soil incorporated applications.

GENERAL MATERIALS AND METHODS

The herbicides used for the experiments in the greenhouse and in the field were:

RH 315, trade name Kerb, N-(1, 1-dimethylpropynyl)-3, 5-dichlorobenzamide, W.P. 75%

Benefin, trade name Balan, N-butyl-N-ethyl- α, α, α-trifluoro-2, 6-dinitro-p-toluidine, E.C. 19.4% (1.5 lb/gallon)

Trifluralin, trade name Treflan, α, α, α -trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine, E.C. 44.5% (4 lb/gallon)

CDEC, trade name Vegadex, 2-chloroallyl diethyldithiocarbamate, E.C. 46.4% (4 lb/gallon)

Bensulide, trade name Prefar, 0, 0-diisopropyl phosphorodithioate S-ester with N-(2-mercaptoethyl)benzenesulfonamide, E.C. 45.2% (4 lb/gallon)

PPG-115, a mixture of propham (IPC), isopropyl carbanilate, E.C. 2 lb/gallon, and PPG-124, experimental inhibitor of microbial degradation from Pittsburg Plate Glass Co., 0.5 lb/gallon.

EL 179, 4-isopropyl-2, 6-dinitro-N, N-dipropylaniline, E.C. 70% (6 lb/gallon)

In some experiments a hand-weeded check was included. In most experiments the soil was seeded with the following weed species:

Italian ryegrass, _Lolium multiflorum_ Lam.

Barnyardgrass, _Echinochloa crusgalli_ (L.) Beauv.

Green foxtail, _Setaria viridis_ (L.) Beauv.

Redroot pigweed, _Amaranthus retroflexus_ L.

Wild mustard, _Brassica campestris_ L.

Many volunteer weeds were found, but only the following species had consistent stand in some experiments:

Common purslane, _Portulaca oleracea_ L.

Common chickweed, _Stellaria media_ (L.) Cyrill

Mouseear chickweed, _Cerastium vulgatum_ L.

Common groundsel, _Senecio vulgaris_ L.

Annual sowthistle, _Sonchus oleraceus_ L.

Spiny sowthistle, _Sonchus asper_ (L.) Hill

Mayweed, _Anthemis cotula_ L.

Prickly lettuce, _Lactuca scariola_ L.

Shepherdspurse, _Capsella bursa-pastoris_ (L.) Medic.

Bittercress, _Cardamine_ spp.

Henbit, _Lamium amplexicaule_ L.

Black mustard, _Brassica nigra_ (L.) Koch

Lambsquarters, _Chenopodium album_ L.

Red deadnettle, _Lamium purpureum_ L.

Annual bluegrass, _Poa annua_ L.

The treatments were accomplished in the following manner:

"Pre-early", treatment applied prior to the emergence of lettuce and weeds, and 34 hours or more before sprinkler irrigation was supplied.

"Pre-late", as above except that sprinkler irrigation was applied immediately after the treatment.

"Post", treatment made after the emergence of lettuce and weeds.

"PPI", treatment applied before the crop was planted, and incorporated into the soil at 2.5-inch depth with power driven rotary tiller, in field studies. Most of the preplant, soil incorporated treatments were worked into the soil immediately after application, but in some cases the incorporation was delayed several hours.

The herbicide response was evaluated on crops and weed species using a 0 to 100 visual rating scale, 0 = plant growth in the check or no effect, and 100 = complete kill of the species, or seedlings very stunted.

The field experiments were conducted at Oregon State University, Vegetable Research Farm, Corvallis, Oregon.

Two types of soil were used in the field experiments. Their characteristics are presented in Table 1.

Table 1. Chemical and mechanical analysis of two soils from Oregon State University Vegetable Research Farm.

Soil	Soil pH	O.M. %	CEC me/100g	Sand %	Silt %	Clay %
Chehalis silty clay loam	6.0	3.43	30.5	1.49	64.13	34.38
Newberg sandy loam	6.0	0.71	12.7	68.56	22.68	8.76

In some field experiments the chemical control was complemented with hand-hoeing in order to eliminate the competition factor in assessing the herbicidal response on lettuce. The time required for this operation was recorded as an indirect measure of the chemical control achieved with the herbicides. In the same experiments, the yield was measured with the purpose of assessing the overall herbicide performance on the crop growth.

GREENHOUSE EXPERIMENTS

Experiment I. Preliminary Screening Trial to Determine the Effect of Several Rates of RH 315 on Lettuce

This experimental compound, RH 315, emerged as a promising herbicide for weed control in lettuce from the 1968 spring trial at Oregon State University.[4]

Materials and Methods

The soil used was medium textured, and appeared to be intermediate in characteristics to the soils listed in Table 1.

The experiment was conducted in plastic containers 13.5" long, 11" wide, and 5" deep. The soil was compacted uniformly as the containers were filled. The bottom of each container was perforated to allow good drainage.

Each container represented an experimental unit, in a completely random design with four replications per treatment. The units were seeded with a lettuce variety of the crisphead type, Cornell 456 MT (Great Lakes group).

All rates of RH 315 were applied preemergence, whereas benefin was applied preplant and incorporated by mixing into the surface

[4] Oregon State University, Farm Crops Department. Spring New Herbicide Evaluation Trial, 1968. (Unpublished Report)

2.5 inches of soil. The application was made using an automatic spray system available in the greenhouse, equipped with an 8002-E nozzle, operated at 25 psi, and calibrated to deliver an application rate of 100 gallons of spray per acre.

All the treatments were sprinkler irrigated by hand immediately after the preemergence treatments were applied. Subsequent irrigation was supplied as needed.

After emergence the stands of weeds and lettuce were recorded as well as the herbicidal response. The lettuce was thinned twice, with an ultimate stand of six plants per experimental unit. All the units were kept free of weeds.

The fresh weights of lettuce were obtained 60 days after planting by cutting the above ground portion of four plants per experimental unit. Fifteen days later fresh weights were determined again on the remaining plants in each experimental unit.

Results

The initial stand of lettuce in the untreated check was higher than in any other treatment but the differences were not statistically significant, as shown in Table 2.

The results of this experiment presented in Table 2 demonstrate that the two weeds present, annual bluegrass and mouseear chickweed, were controlled at all rates of RH 315 tested. Benefin

Table 2. Effects of rates of RH 315 on weed control and lettuce growth. Experiment I.

Treatment	lb ai/A	Percent chemical control[1]: Annual bluegrass	Percent chemical control[1]: Mouseear chickweed	Initial stand of lettuce plants/plot[2]	Fresh weights of lettuce: g/plant, 60 days after planting	Fresh weights of lettuce: g/plant, 75 days after planting
RH 315	1.35	100	100	5.2	7.5	32.3
RH 315	2.70	100	100	4.9	6.8	44.0
RH 315	4.05	100	100	5.0	7.6	37.0
RH 315	5.40	100	100	5.0	9.1	39.8
RH 315	8.10	100	100	5.2	7.8	33.8
Benefin	0.70	99	90	4.9	5.2	29.8
Check	-	0	0	5.7	7.5	30.3
LSD .05				1.1	3.6	13.4
LSD .01				1.5	4.8	18.1

[1] Observation 30 days after planting, recorded as visual rating: 0 = plant growth in the check or no effect, and 100 = complete kill or seedlings very stunted.

[2] Average values from square root transformation.

performance was very good on annual bluegrass but less effective on mouseear chickweed, at the rate of 0.7 lb/A.

No adverse effect from any rate of RH 315 appeared on the fresh weights of lettuce when determined 60 and 75 days after planting. Benefin at 0.7 lb/A appeared to be detrimental at the early stages of lettuce growth under the conditions of this experiment. This effect appeared in the fresh weight 75 days after planting, but the difference with the check was not statistically significant.

Experiment II. Response of Three Rates of RH 315 on Lettuce Growth and Weed Control as Tested on Three Soil Types

In general, as herbicidal behavior, both on crop growth and weed control, is conditioned by the type of soil, this experiment was aimed at determining the lettuce tolerance to RH 315 as affected by soil type.

Materials and Methods

The three soils used are classified as Chehalis silty clay loam, Newberg sand, and Semiahmoo muck, but no analysis was obtained. The experiment was conducted in the same manner described in Experiment I.

Four levels of RH 315, including a check (zero level), were tested in each soil. All treatments were sprinkler irrigated by hand immediately after the application of the herbicides. Subsequent irrigation was supplied as needed.

The treatments in the sandy soil were fertilized weekly, whereas those in the silty clay loam and muck soil were fertilized at 15-day intervals. The fertilizer was composed of N 23%, P_2O_5 21%, and K_2O 17%. It was applied as 0.4% solution at the rate of 10 fluid ounces per experimental unit.

After emergence the stands of weeds and lettuce were recorded. The lettuce was thinned twice before fresh weight was obtained the first time 30 days after planting. Fresh weights of lettuce were also obtained 40, 50 and 65 days after planting. After each observation the weeds were removed.

Results

The initial stand of lettuce in the untreated check was higher than in any other treatment both in the silty clay loam and the muck soil but the differences were not statistically significant. The same pattern was observed in the sandy soil except that the average stand in this soil was about 40% lower than that of the other two types of soil.

The results of this experiment are presented in Tables 3 and 4. Table 3 shows the fresh weights of lettuce at four different intervals from planting date. No significant differences were observed among

Table 4. Effects of three rates of RH 315 on the control of three weed species as affected by soil type. Experiment II.

			Observation 20 days after planting[1]						40 days after planting[2]		
			Barnyardgrass		Pigweed		Mustard		Barnyardgrass	Pigweed	Mustard
Soil type	Treatment	ai lb/A	Number	%	Number	%	Number	%	Number	Number	Number
Muck soil	RH 315	1.35	20	30	89	0	32	0	15	39	31
	RH 315	2.70	3	95	76	10	31	0	2	9	6
	RH 315	5.40	1	99	55[c]	85	18	20	0	0	0
	Check	-	34	0	131	0	63	0	76	69	36
Silty clay	RH 315	1.35	0	100	57[c]	85	21	0	0	0	0
	RH 315	2.70	0	100	42[c]	98	16	50	0	0	0
	RH 315	5.40	0	100	31[c]	100	19	75	0	0	0
	Check	-	76	0	256	0	68	0	94	64	25
Sandy soil	RH 315	1.35	0	100	16[c]	98	37[c]	90	0	0	0
	RH 315	2.70	0	100	0	100	36[c]	95	0	0	0
	RH 315	5.40	0	100	0	100	28[c]	98	0	0	0
	Check	-	91	0	88	0	44	0	50	67	30

[1] Number = number of weed seedlings/4 sq ft; % = percent chemical control from visual rating; c = seedlings stunted at the cotyledon stages. All weeds were removed after evaluation.

[2] This observation relates to new seedlings from late emergence. Number = weed seedlings/4 sq ft.

levels of RH 315 within each soil except for the sandy soil when fresh weights were obtained 50 and 65 days after planting. The highest rate of RH 315 tested (5.4 lb/A) appeared to be detrimental to lettuce in the sandy soil, but the difference with the check was only significant at the 5% probability level when fresh weights were obtained 50 days after planting, and significant at the 1% probability level when fresh weights were obtained 65 days after planting.

Analysis of variance of fresh weights taken 65 days after planting showed significant interaction between soil types and rates of RH 315. As can be seen in Figure 1, most of the interaction is derived from the highest rate of RH 315 (5.4 lb/A) in the sandy soil which implies a difference in magnitude of response when compared with the same rate on the other two types of soil.

Table 3 shows that the differences among soils in all the comparisons were significant at the 1% probability level when fresh weights were taken 30, 40, or 50 days after planting. The muck soil always gave the highest yield, whereas the sandy soil gave the lowest. This trend was similar for the fresh weights obtained 65 days after planting, but the significant interaction, rate X soil, does not permit accurate comparisons.

Figures 2, 3 and 4 present the fresh weights as percent of control at different intervals from planting for the three soil types. They show that there is a decrease in the rate of lettuce growth about 40

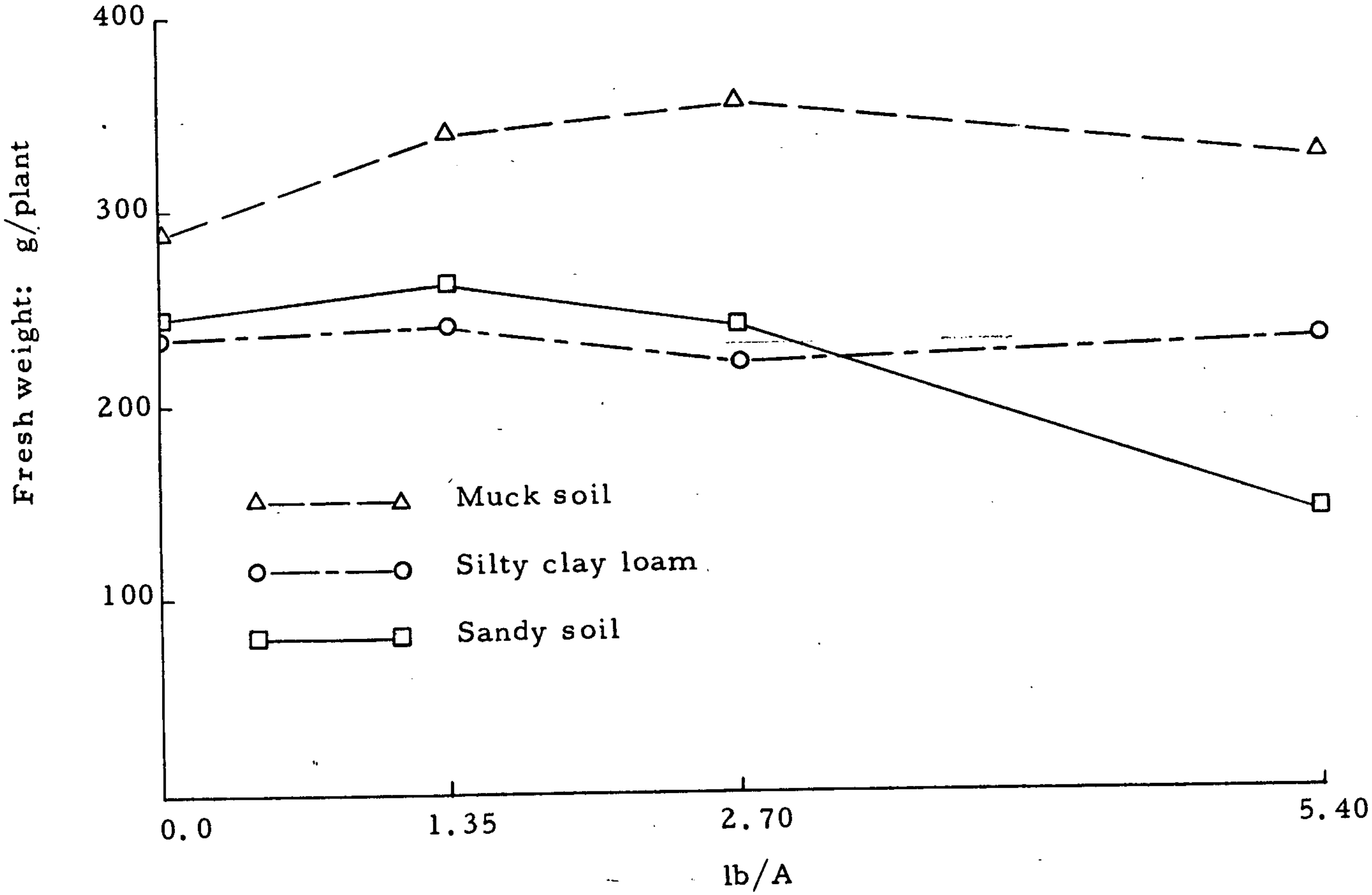

Figure 1. Effect of various levels of RH 315 on the fresh weight of lettuce in three soil types.

days after planting under the conditions of this experiment as a response to the herbicide, and this is more conspicuous and definite in the sandy soil. The relative position of these growth curves in respect to the 100 percent line is indicative of the crop response to the herbicide. Figure 2 shows that all rates of RH 315 exert a detrimental effect on the lettuce growth which is overcome on the lower levels later in the development of the lettuce plants from about 65 days after planting.

Figure 3 shows that RH 315 was not detrimental to the lettuce growth at any stage of growth in the muck soil. The results in the silty clay loam are intermediate when compared with those of the other two types of soil as shown in Figure 4. No striking changes with respect to the check appeared at the later stages of growth.

Table 4 shows the herbicidal response on three weeds. Barnyardgrass was completely controlled at all rates in both the sandy soil and silty clay loam. In the muck soil good control was achieved with the rate of 2.7 lb/A. Some late emergence occurred with this rate of RH 315, whereas none did at the rate of 5.4 lb/A with almost complete control.

Pigweed emerged in all treatments except at the higher rates in the sandy soil. Very good control was achieved at any rate in the sandy soil and with the higher rates in the silty clay loam. The control was also poor with the lowest rate of RH 315 in the silty clay

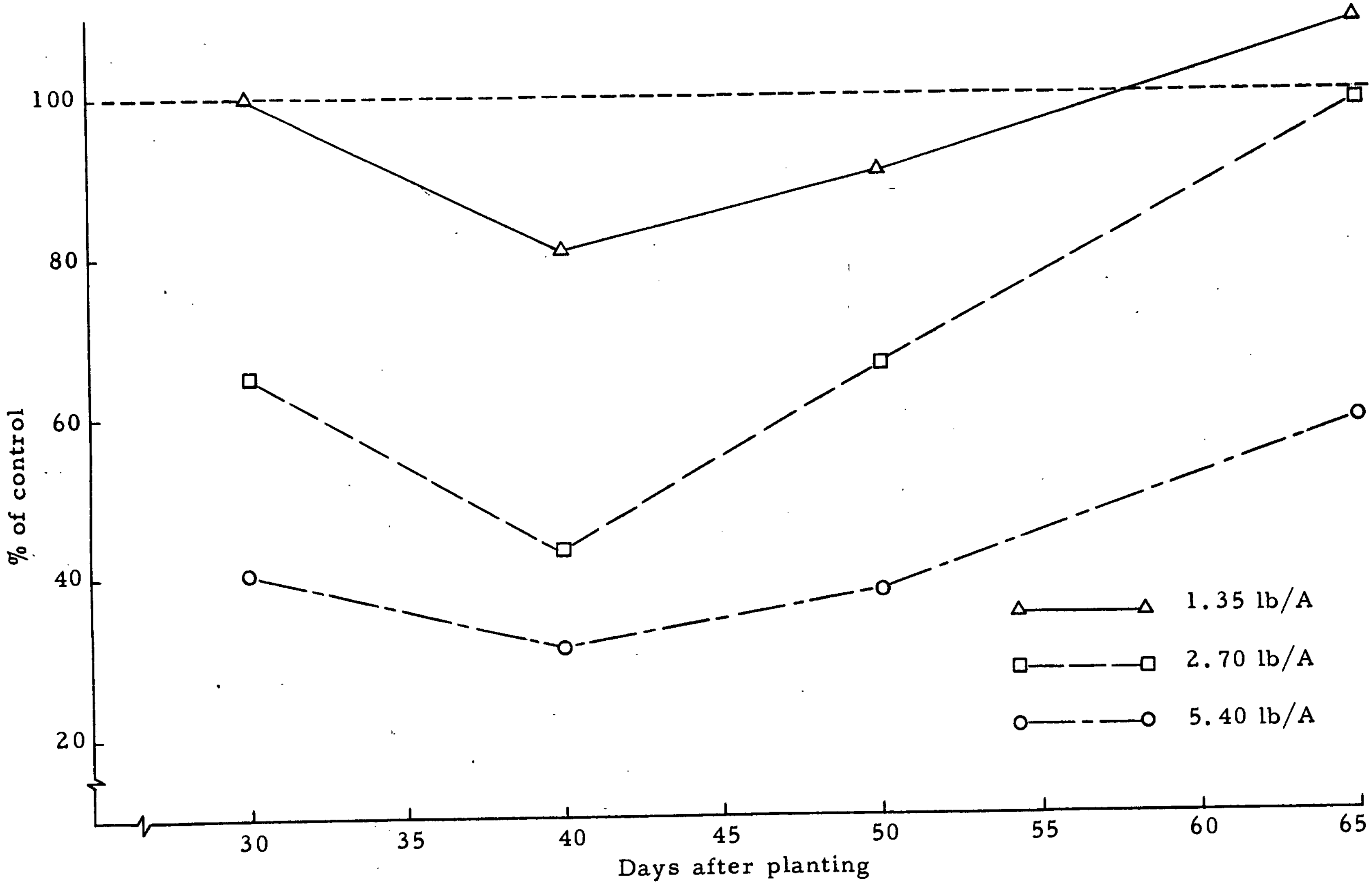

Figure 2. Effect of three rates of RH 315 on lettuce grown in sandy soil. Fresh weights are expressed as percent of control.

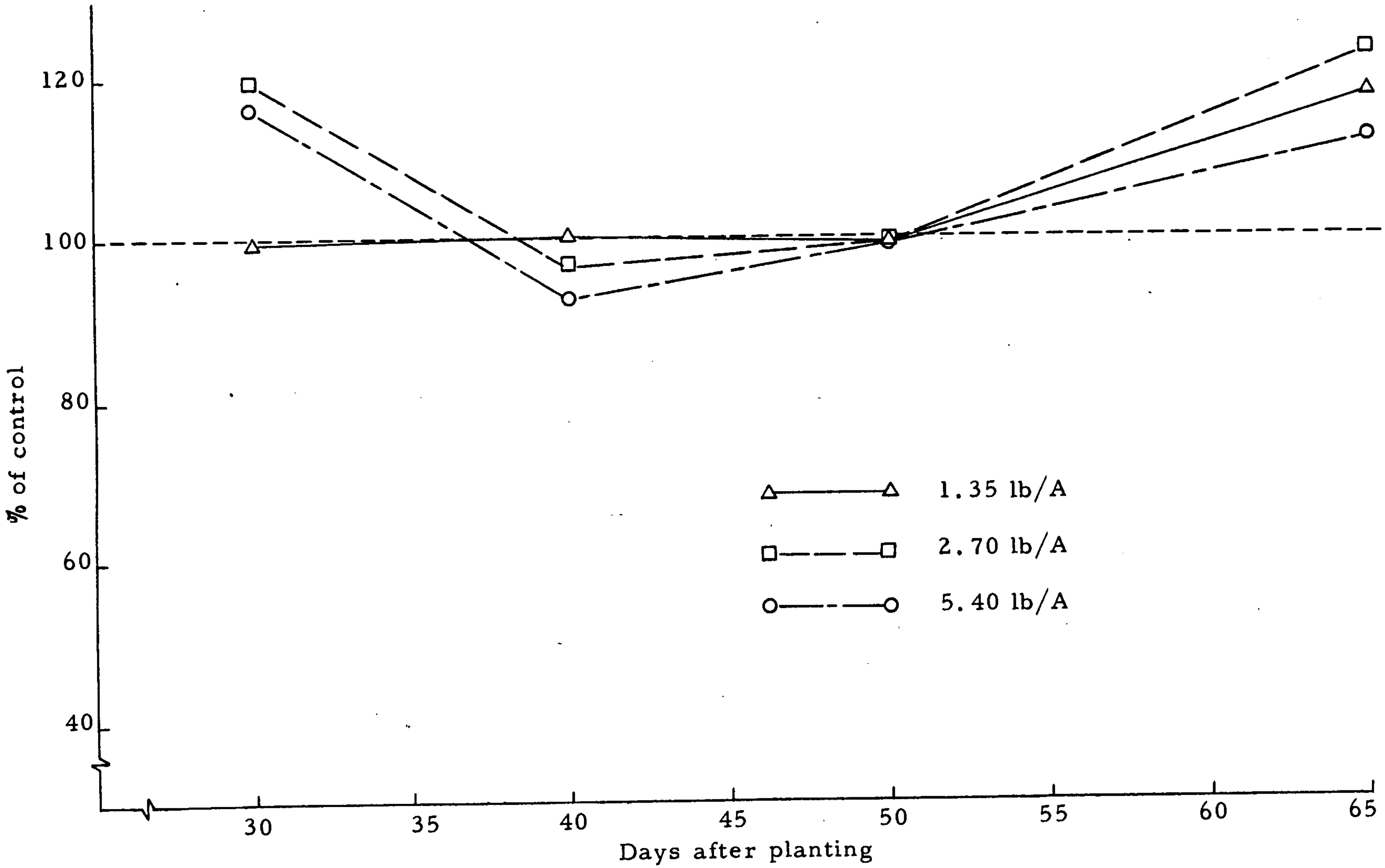

Figure 3. Effect of three rates of RH 315 on lettuce grown in muck soil. Fresh weights are expressed as percent of control.

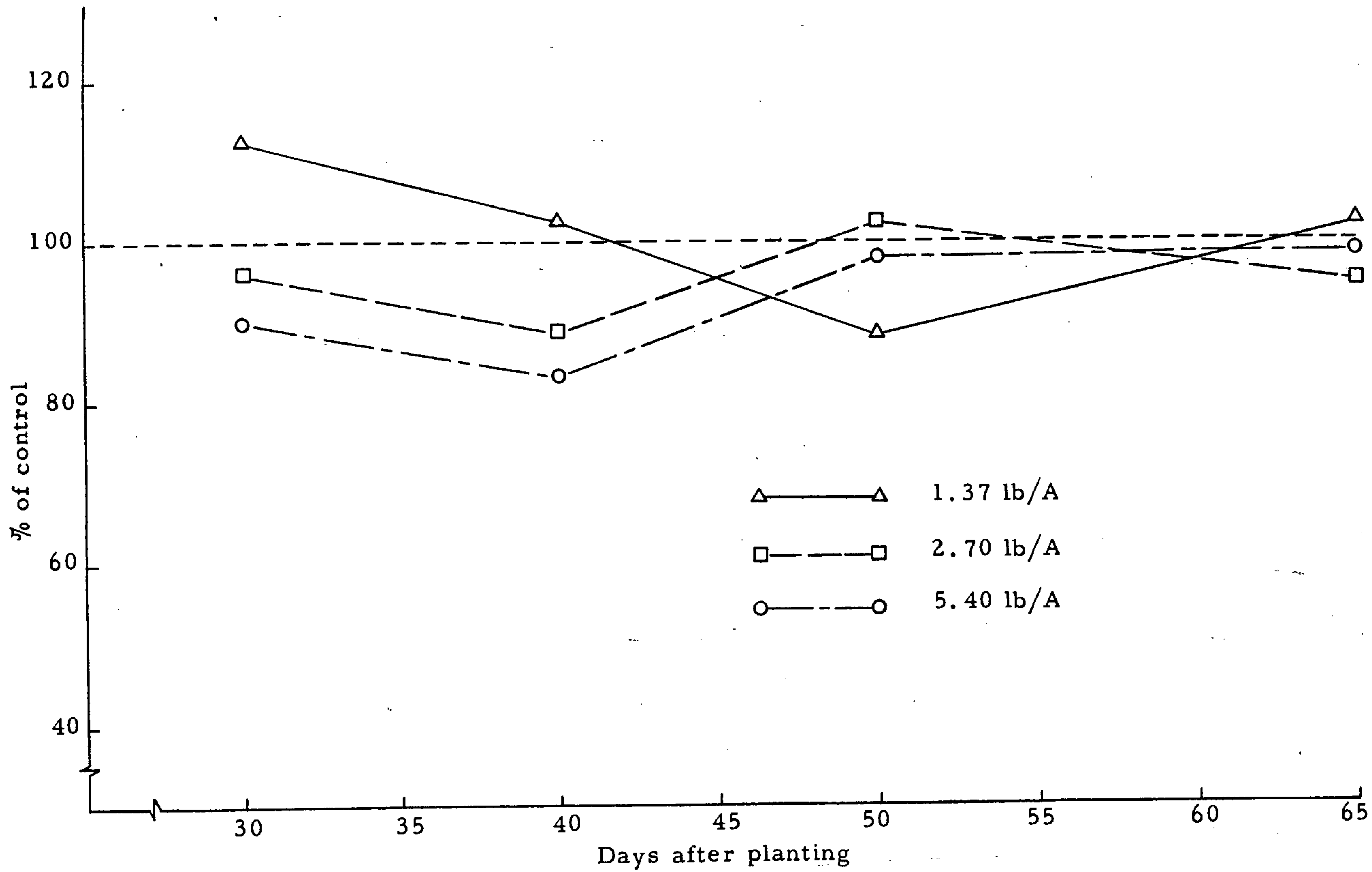

Figure 4. Effect of three rates of RH 315 on lettuce grown in silty clay loam. Fresh weights are expressed as percent of control.

loam. Poor control was obtained even with the highest rate in the muck soil. The control was also poor with the lowest rate of RH 315 in the silty clay loam. With the lower rates in the muck soil there was almost no control of pigweed, but only with the lowest rate the late emergence of pigweed was of some significance, about 57% of that in the check.

Mustard emerged in all treatments and was quite well controlled at all rates in the sandy soil. In the silty clay loam there was poor control even with the highest rate, and almost no control was achieved at any rate in the muck soil. Considerable late emergence of mustard occurred with the lowest rate in the muck soil, about 86% of that in the check. Some later emergence also occurred with the intermediate rate.

FIELD EXPERIMENTS

In general, herbicide experiments carried out in the greenhouse are only suggestive of herbicide performance, for crop plants and weeds are not subjected to the natural stresses of field conditions. Consequently, field experiments were planned to study herbicide behavior as affected by two soil types and different environmental conditions.

Experiment III. Performance of RH 315 Compared with Other Herbicides in Controlling Weeds in Lettuce in a Silty Clay Loam Soil

Materials and Methods

This experiment was conducted in a randomized complete-block design with four replications. Plot size was 8' x 15'. The treatments were applied with a plot sprayer equipped with a pressurized tank, operated at 30 psi, and calibrated to deliver an application rate of 45 gallons of spray per acre. Planting of lettuce was made on May 22, 1969.

Herbicides applied prior to planting of lettuce and weeds were worked into the soil to a depth of 2.5 inches by means of a tractor-powered rotary tiller.

Lettuce, coated seed with clay[5], of the crisphead cultivar Mesa

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[5] Lite-Coat, trade name from Asgrow Seed Company, Orange, Connecticut.

659 MI was planted with a precision planter at 12 inches in the row and three spacings between rows: four rows spaced ten inches apart, three rows 15 inches apart, and two rows 20 inches apart. Fertilizer of the formula 8-24-8 was banded at planting at the rate of 0.05 pound per linear foot row.

Between planting and the application of the preemergence herbicides, one sprinkler irrigation was supplied and rain fell amounting to a total of 0.65 inch. The preemergence treatments (RH 315) were applied on moist soil on May 28, 1969. Sprinkler irrigation was applied five days after the preemergence application. Thereafter additional irrigation was supplied as needed.

After emergence the stands of weeds and lettuce were recorded as well as the herbicidal response. A week after emergence all plots were weeded by hand-hoeing, except one check which was kept unweeded through the season. This operation was repeated two weeks later.

The lettuce was harvested on July 31, and weights of untrimmed and trimmed heads were taken.

Results

The stand of lettuce was similar in all treatments and no detrimental effect was observed at any stage of growth.

The results in Table 5, show that benefin gave the highest yield

Table 5. Effects of herbicides on lettuce and weeds in a silty clay loam soil. Experiment III.

Treatment	ai lb/A	Lettuce yield: lb/head		Percent chemical control[1]			Hand-weeding
		Untrimmed	Trimmed	Grasses[2]	Pigweed	Mustard	Man hours/A
RH 315	1.5	2.28	1.25	57	20	5	121
RH 315	3.0	2.35	1.31	80	31	12	116
RH 315	5.0	2.35	1.32	96	87	62	64
Benefin	1.0	2.52	1.39	100	100	0	37
Benefin + PPG 115	1.0 4.0	2.38	1.26	100	98	20	38
RH 315 + PPG 115	1.5 4.0	2.34	1.32	98	40	17	101
Hand-weeded check	-	2.14	1.13	0	0	0	159
Check (Not weeded)	-	0.00	0.00	0	0	0	-
LSD .05		0.28	0.15				
LSD .01		0.38	0.21				

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] Grasses were: Italian ryegrass, Lolium multiflorum Lam.; barnyardgrass, Echinochloa crusgalli (L.) Beauv.; and green foxtail, Setaria viridis (L.) Beauv.

of lettuce and the difference with the hand-weeded check was highly significant, but no significance was found among chemical treatments either when the untrimmed or trimmed heads were considered. The lettuce heads in the hand-weeded check were immature at the time of harvest, whereas those of the other treatments were fully formed. There was almost no lettuce growth in the unweeded check, except for a few weak plants smothered by a dense stand of weeds.

Excellent control of Italian ryegrass, barnyardgrass, green foxtail, and pigweed was achieved with benefin, but no effect was observed on wild mustard. Similar performance was obtained with the mixture of benefin and propham. On the other hand, RH 315 performed poorly since only fair control was obtained at the higher rates. As it will be discussed later, this low degree of herbicidal activity can be traced to the delay in supplying sprinkler irrigation after the herbicide application.

The degree of chemical control of weeds was inversely correlated to the amount of time required for hand-weeding as shown in Table 5.

Table 6 shows the stand of weeds as observed a week after emergence and before the first hand-hoeing was carried out. The weed population was very high in both checks, and in many treated plots.

Table 6. Effects of herbicides on the stand of five weed species[1] in a silty clay loam soil. Experiment III.

Treatment	ai lb/A	Number of plants per square meter					
		Barnyardgrass	Green foxtail	Ryegrass	Pigweed	Mustard	Total
RH 315	1.5	103	4	40	228	36	411
RH 315	3.0	50	10	54	267	35	416
RH 315	5.0	32	0	17	147	25	221
Benefin	1.0	8	0	0	2	70	80
Benefin + PPG 115	1.0 4.0	6	0	0	8	78	92
RH 315 + PPG 115	1.5 4.0	56	4	0	297	54	411
Hand-weeded[2] check	-	91	20	63	472	75	721
Check (Not weeded)	-	105	12	132	367	98	714

[1] Three samples of 0.04 m^2 were taken at random in each plot. The data from the four replications were averaged, and the results expressed as number of plants per square meter.

[2] Hand-weeding was carried out a week after emergence soon after the stand of weeds was recorded.

Experiment IV. Performance of RH 315 Compared with Other Herbicides in Controlling Weeds in Lettuce in a Sandy Loam Soil

This experiment was carried out in much the same fashion as experiment III except that the soil was a sandy loam, and sprinkler irrigation was supplied immediately after the preemergence treatments were applied.

The lettuce was harvested on August 6, and weights of untrimmed and trimmed heads were taken.

Results

The stand of lettuce was similar in all treatments and no injury to the crop was observed at any stage of growth.

The results of this experiment are presented in Table 7. The chemical treatments gave higher yield of lettuce than the hand-weeded check, and the differences were significant at 1% probability level when the untrimmed heads are considered. The results were similar with the trimmed heads except that the difference in yield between the mixture of benefin plus PPG 115 and the hand-weeded check was significant only at the 5% probability level.

RH 315 at 5 lb/A gave the highest yield, but the lettuce obtained from this treatment was somewhat overmature. The earlier maturation may be due to the complete control of weeds achieved with this

Table 7. Effects of herbicides on lettuce and weed growth in a sandy loam soil. Experiment IV.

Treatment	ai lb/A	Lettuce yield: lb/head Untrimmed	Trimmed	Percent chemical control[1] Grasses[2]	Pigweed	Mustard	Hand-weeding Man hours/A
RH 315	1.5	2.89	1.62	98	81	65	49
RH 315	3.0	2.81	1.58	100	97	88	26
RH 315	5.0	3.04	1.73	100	100	99	12
Benefin	1.0	2.95	1.59	99	100	5	30
Benefin + PPG 115	1.0 4.0	2.82	1.52	100	100	85	26
RH 315 + PPG 115	1.5 4.0	2.79	1.57	100	98	95	25
Hand-weeded check	-	2.42	1.30	0	0	0	159
Check (Not weeded)	-	0.00	0.00	0	0	0	-
LSD .05		0.23	0.17				
LSD .01		0.32	0.24				

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] The grasses were: Italian ryegrass, Lolium multiflorum Lam.; barnyardgrass, Echinochloa crusgalli (L.) Beauv. and green foxtail, Setaria viridis (L.) Beauv.

Table 8. Effects of herbicides on the stand of five weeds in a sandy loam soil. Experiment IV.

Treatment	ai lb/A	Number of plants per square meter[1]					
		Barnyardgrass	Green foxtail	Ryegrass	Pigweed	Mustard	Total
RH 315	1.5	14^s	0	0	141^c	69^c	224
RH 315	3.0	0	0	0	46^c	59^c	105
RH 315	5.0	0	0	0	0	20^c	20
Benefin	1.0	0	0	23^s	0	107	130
Benefin + PPG 115	1.0 4.0	0	0	0	0	109	109
RH 315 + PPG 115	1.5 4.0	6^s	0	0	109^c	81^c	196
Hand-weeded[2] check	-	91	42	133	369	87	722
Check (Not weeded)	-	63	40	148	303	79	633

[1] Three samples of 0.04 m^2 were taken at random in each plot. The data from the four replications were averaged, and the results expressed as number of plants per square meter.

[2] Hand-weeding was carried out two days after the stand of weeds was recorded.

s = stunted seedlings; c = seedlings at the cotyledon stage. In the check and non-effective treatments, pigweed had six to eight true leaves, and mustard four to six.

more effective on ryegrass and possesses some activity on mustard.

Experiment V. Performance of Several Herbicides in Controlling Weeds in Lettuce in a Silty Clay Loam Soil, and Their Residual Effect on Other Vegetable Crops

This experiment was carried out with the purpose of comparing various herbicides and several rates of RH 315 in regard to their performance on weeds and the tolerance of lettuce under two types of irrigation management. The residual effect on rotation crops was also evaluated.

Materials and Methods

The experiment was conducted in a randomized complete-block design with four replications. The plots measured 8' x 23'. The soil was a Chehalis silty clay loam with an analysis as is given in Table 1.

Trifluralin, benefin, bensulide and EL 179 were applied prior to planting and soil incorporated with rotary tiller at 2.5-inch depth immediately after application.

The weeds and lettuce were planted on July 7, 1969. The weed seed was broadcast by hand; the coated seed of lettuce was planted in the same manner as described in Experiment III. In addition, three rows were planted with bare seed of lettuce at the rate of 6 lb/A, and one foot spacing between rows. The crisphead cultivar Mesa 659 MI was used for both the bare and coated seed.

Three rows of bush beans, cultivar OSU 58, were planted in each plot with the purpose of evaluating the tolerance to the herbicides tested.

After planting, the "pre-early" treatments of RH 315 were applied 34 hours prior to irrigation. The "pre-late" treatments of RH 315 and CDEC were applied immediately before sprinkler irrigation. Further irrigation was applied as needed.

After emergence the stand of weeds, lettuce, and bush beans were recorded as well as the herbicidal response. The latter was reassessed three weeks later. Only the check was hand-weeded.

About 60 days after planting, the soil in the experimental area was carefully rotary tilled twice, once each in opposite directions, at 4-inch depth; after packing the soil, it was planted with one or two rows of the following vegetables: bush beans (OSU 58), sweet corn (Jubilee), cucumbers (Hybrid NK 805), red beets (Detroit Dark Red), and spinach. Of ten plots which had not been previously treated but used as check, three plots were sprayed with RH 315 at 1.5 lb/A, three plots at 2.5 lb/A, and four plots left as check. Immediately after these treatments were applied, the entire experiment was sprinkler irrigated. Thereafter, additional watering was supplied as needed.

Results

The stand of lettuce was similar in all treatments except for the two highest rates of RH 315, 5 and 10 lb/A, which affected the emergence and growth of lettuce as can be seen in the visual rating shown in Table 9. Furthermore, this effect was more marked in the subplots planted with the coated seed than in those with the bare seed. In the latter, only RH 315 at 10 lb/A affected the growth and stand of lettuce.

Bush beans appeared to be less tolerant to RH 315 than lettuce. The detrimental effect on the stand and growth ranged from 12% overall reduction of plant development with 3.5 lb/A, to 75% with 10 lb/A. The other treatments affected neither beans nor lettuce.

The evaluation of the residual effect of the treatments is presented in Table 9. The emergence of spinach was poor even in the check, thus no observation was made. The results show that RH 315 up to the rate of 2.5 lb/A had little or no residual action on the species tested, 60 days after the treatments were applied. At higher rates, the residual effect increased with the application rate. No important differences were observed between the pre-late and pre-early treatments.

The immediate effect of RH 315 at both rates tested, 1.5 and 2.5 lb/A, application made immediately after planting the vegetables for the residue test, was highly detrimental to sweet corn, cucumbers,

Table 9. Residual effects of herbicides on vegetable crops in a silty clay loam soil. Experiment V.

			Percent reduction of growth[4]								
			Immediate effect			Residual effect					
			Lettuce		Bush	Days after	Bush	Sweet		
Treatment	ai lb/A	Type of application	Coated seed	Bare seed	beans	treatment[5]	beans	corn	Cucumbers	Red beets
RH 315	1.5	Pre-late[1]	0	0	0	60	0	0	0	0
RH 315	2.5	"	0	0	0	60	0	3	5	3
RH 315	3.5	"	0	0	12	60	10	5	17	8
RH 315	5.0	"	15	0	25	60	10	30	60	68
RH 315	10.0	"	70	20	75	60	33	95	100	98
RH 315	1.5	Pre-early[2]	0	0	0	62	0	0	0	0
RH 315	2.5	"	0	0	0	62	0	8	8	5
RH 315	3.5	"	0	0	0	62	10	8	13	8
Trifluralin	0.75	PPI[3]	0	0	0	82	0	33	30	30
Benefin	1.0	"	0	0	0	82	0	0	8	10
EL 179	1.0	"	0	0	0	82	0	3	10	20
EL 179	2.0	"	0	0	0	82	0	5	10	30
Bensulide	6.0	"	0	0	0	82	0	53	0	10
CDEC	5.0	Pre-late[1]	0	0	0	60	0	3	20	5
RH 315	1.5	"	-	-	-	0	0	80	90	96
RH 315	2.5	"	-	-	-	0	5	100	98	100

[1]Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied immediately after application.

[2]Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied 34 hours after application.

[3]Preplant soil incorporated treatments.

[4]Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[5]Interval between herbicide application and planting.

and red beets. Only little reduction of growth was observed on bush beans at the rate of 2.5 lb/A.

Trifluralin proved to have considerable residual action on sweet corn, cucumbers, and red beets, but no effect on bush beans, 82 days after the treatment was applied. On the other hand, benefin appeared to have much less residual activity on all species tested than trifluralin. EL 179 also showed little residual activity except on red beets where the remaining residue from both rates tested, 1 and 2 lb/A, was noticeably detrimental to this species. Bensulide demonstrated high residual activity on sweet corn only. In all cases, the residual action of trifluralin, benefin, EL 179, and bensulide, was tested 82 days after the treatments were applied. CDEC showed some residual action on cucumbers only, as tested 60 days after application.

Table 10 presents the herbicidal response on five weed species. Italian ryegrass and barnyardgrass were completely controlled by RH 315 at 2.5 lb/A or more, when sprinkler irrigation was applied immediately after application (pre-late treatments). Under the same conditions the rate of 1.5 lb/A gave satisfactory control of both species. Delaying sprinkler irrigation 34 hours after application caused reduction of the herbicidal action, which was more pronounced on barnyardgrass than on Italian ryegrass at the rate of 1.5 lb/A. The other herbicides tested gave very good control of these two grasses, except bensulide which was ineffective on Italian ryegrass

Table 10. Effects of herbicides on the control of five weed species in a silty clay loam soil. Experiment V.

Treatment	ai lb/A	Type of application	Percent chemical control[1]: 40 days after planting					
			Mustard	Groundsel	Pigweed	Ryegrass	Barnyardgrass	Average
RH 315	1.5	Pre-late[2]	10	0	40	87	90	45
RH 315	2.5	"	62	0	76	100	100	68
RH 315	3.5	"	85	0	91	100	100	75
RH 315	5.0	"	90	5	100	100	100	79
RH 315	10.0	"	100	30	100	100	100	86
RH 315	1.5	Pre-early[3]	18	0	20	76	54	33
RH 315	2.5	"	50	0	43	91	91	55
RH 315	3.5	"	65	0	79	100	98	68
Trifluralin	0.75	PPI[4]	0	0	100	100	100	60
Benefin	1.0	"	0	0	74	99	100	55
EL 179	1.0	"	0	0	91	90	100	56
EL 179	2.0	"	0	0	99	100	100	60
Bensulide	6.0	"	0	0	13	10	80	21
CDEC	5.0	Pre-late[2]	0	0	99	98	95	58

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied immediately after application.

[3] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied 34 hours after application.

[4] Preplant soil incorporated treatments.

and provided only fair control of barnyardgrass.

Pigweed was controlled very well by RH 315 only at the rate of 5 lb/A or more, and was controlled satisfactorily with 3.5 lb/A. The lowest rates provided poor control. The delay in supplying sprinkler irrigation brought about considerable reduction of the herbicidal action on this species. Trifluralin, CDEC, and EL 179 at 2 lb/A gave excellent control of pigweed. EL 179 at 1 lb/A was satisfactory, whereas benefin at the same rate was poor, and bensulide almost ineffective in controlling this weed.

RH 315 proved to have some activity on wild mustard, in fact at 3.5 and 5 lb/A the control was satisfactory. The other herbicides were ineffective.

Groundsel was not controlled by any of the chemicals tested.

This experiment showed that a 34-hour delay in supplying sprinkler irrigation after the application of RH 315 caused noticeable reduction of its herbicidal activity.

Experiment VI. Performance of Several Herbicides in Controlling Weeds in Lettuce in a Sandy Loam Soil, and Their Residual Effect on Other Vegetable Crops

The objectives of this experiment were essentially the same as those described in Experiment V.

Materials and Methods

This experiment was carried out in the same manner as Experiment V except that the soil was a sandy loam, and there was variation in timing the incorporation of the preplant applied treatments. Due to weather conditions, trifluralin, benefin and EL 179 were incorporated into the soil 68 hours after application. Trifluralin and benefin, in other treatments, were incorporated properly, that is, immediately after application.

The pre-early treatments of RH 315 were sprinkler irrigated 46 hours after application. No rain occurred during this period.

Results

Table 11 shows the herbicide response on six weeds. Italian ryegrass was very well controlled by RH 315 at 1.5 lb/A or more, when sprinkler irrigation was supplied immediately after the herbicide application. Under the same conditions the rate of 1 lb/A gave satisfactory control. The 46-hour delay in applying sprinkler irrigation did not cause important reduction of the herbicide activity of this compound in controlling Italian ryegrass.

Trifluralin when properly incorporated provided excellent control of Italian ryegrass, but the 68-hour delay in incorporating it, caused more than 90% reduction of its herbicidal activity. Benefin

Table 11. Effects of herbicides on the control of six weed species in a sandy loam soil. Experiment VI.

Treatment	ai lb/A	Type of application	Percent chemical control[1]: 60 days after planting						
			Mustard	Groundsel	Pigweed	Purslane	Ryegrass	Barnyardgrass	Average
RH 315	1.0	Pre-late[2]	18	0	74	90	89	80	59
RH 315	1.5	"	63	0	94	100	96	93	74
RH 315	2.0	"	91	0	100	100	100	99	82
RH 315	4.0	"	100	10	100	100	100	100	85
RH 315	8.0	"	100	40	100	100	100	100	90
RH 315	1.5	Pre-early[3]	71	0	79	80	91	80	67
RH 315	2.0	"	86	0	93	98	100	99	79
RH 315	4.0	"	100	0	100	100	100	100	83
Trifluralin	0.75	PPI[4]	0	0	37	60	7	13	20
Benefin	0.75	"	0	0	47	80	45	55	38
EL 179	1.0	"	0	0	68	60	33	83	41
EL 179	2.0	"	0	0	100	100	94	100	66
Trifluralin	0.75	PPI[5]	0	0	100	100	98	100	66
Benefin	0.75	"	0	0	75	85	89	93	57

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied immediately after application.

[3] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied 46 hours after application.

[4] Preplant soil incorporated treatments at 2.5 inch depth with rotary tiller 68 hours after application.

[5] Preplant soil incorporated treatments at 2.5 inch depth with rotary tiller immediately after application.

was satisfactory for the control of Italian ryegrass, whereas the delay in incorporating it brought about 50% loss of its herbicidal activity. EL 179 at 2 lb/A gave very good control of Italian ryegrass in spite of the delayed incorporation.

The performance of the herbicides tested on barnyardgrass was similar to that on Italian ryegrass except that the nitroanilines (trifluralin, benefin and EL 179) appeared to be somewhat more effective on barnyardgrass than on annual ryegrass. The reverse was true for RH 315.

Purslane was completely controlled by RH 315 at 1.5 lb/A or more, when sprinkler irrigation was supplied immediately after the herbicide application. Under the same conditions the rate of 1 lb/A was satisfactory. The 46-hour delay in applying sprinkler irrigation caused some reduction of the herbicidal activity.

Trifluralin when incorporated immediately after application completely controlled purslane and pigweed. The 68-hour delay in incorporating it caused 40% reduction of its activity on purslane, and more than 60% on pigweed. On the other hand, benefin performance was satisfactory on purslane but poor on pigweed even when properly incorporated. The reduction of its activity due to the delay of incorporation was less pronounced than with trifluralin. EL 179 at 2 lb/A gave excellent control of both weeds in spite of the delay in incorporating it.

Table 12. Residual effects of herbicides on vegetable crops in a sandy loam soil. Experiment VI.

			Percent reduction of growth[1]							
			Immediate effect			Residual effect				
			Lettuce							
Treatment	ai lb/A	Type of application	Coated seed	Bare seed	Bush beans	Days after treatment[2]	Bush beans	Sweet corn	Cucumbers	Red beets
RH 315	1.0	Pre-late[3]	0	0	0	60	0	0	0	0
RH 315	1.5	"	0	0	15	60	0	4	0	0
RH 315	2.0	"	0	0	45	60	0	6	0	40
RH 315	4.0	"	20	10	80	60	3	28	50	70
RH 315	8.0	"	85	55	100	60	33	93	100	100
RH 315	1.5	Pre-early[4]	0	0	0	63	0	0	0	0
RH 315	2.0	"	0	0	30	63	5	5	0	5
RH 315	4.0	"	10	0	75	63	10	25	20	20
Trifluralin	0.75	PPI[5]	0	0	0	85	0	20	10	65
Benefin	0.75	"	0	0	0	85	0	18	10	20
EL 179	1.0	"	0	0	0	85	0	13	0	45
EL 179	2.0	"	0	0	0	85	0	28	0	90
Trifluralin	0.75	PPI[6]	0	0	0	82	0	45	35	70
Benefin	0.75	"	0	0	0	82	0	10	10	10
RH 315	1.0	Pre-late[3]	-	-	-	0	30	80	100	65
RH 315	2.0	"	-	-	-	0	57	100	100	100

[1] Evaluation by visual rating: 0 = no effect; 100 = complete kill.

[2] Interval between herbicide application and planting.

[3] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied immediately after herbicide application.

[4] Preemergence treatments. Sprinkler irrigation amounting 0.8 inch was supplied 46 hours after herbicide application.

[5] Preplant soil incorporated treatments at 2.5 inch depth with rotary tiller 68 hours after herbicide application.

[6] Preplant soil incorporated treatments at 2.5 inch depth with rotary tiller immediately after herbicide application.

observation was recorded. The results show that RH 315 up to the rate of 2 lb/A had little or no residual action on the species tested, except for red beets which were considerably affected by the residue from RH 315 at 2 lb/A, when tested 60 days after this treatment was applied.

The most susceptible species appeared to be red beets followed closely by cucumbers. The bush beans were the least susceptible, whereas sweet corn was intermediate. The difference between the pre-late and pre-early treatments was considerable only for red beets and cucumbers in that a 46-hour delay in supplying sprinkler irrigation after the treatments were applied, caused considerable reduction of the residual life of RH 315. However, no difference was observed when bush beans and sweet corn are considered.

The immediate effect of RH 315 at both rates tested, 1 and 2 lb/A, with application made immediately after planting the vegetables for the residue test, was highly detrimental to cucumber, sweet corn and red beets, but this effect was less pronounced on bush beans.

Experiment VII. The Effect of Irrigation Management and Soil Moisture at the Time of Application on the Herbicidal Action of RH 315

Since some experiments gave erratic results with RH 315, the objective of this experiment was to determine the effect of soil moisture at time of application, and the influence of delaying sprinkler irrigation after the treatment was applied, on the herbicidal performance of two rates of RH 315 in a sandy loam soil.

Materials and Methods

The experiment was carried out in a randomized complete-block design with four replications. The plot size was 10' x 7.5'. The treatments were applied in the same way as described in Experiment III.

Three days before the treatments were applied, the soil was prepared and seed of pigweed and Italian ryegrass was planted. The treatments were applied between September 11 and 14, 1969. The first irrigation on each treatment amounted to one inch. Subsequent irrigation was supplied as needed.

After emergence the stand of weeds was recorded as well as the herbicidal response. An additional observation was made 50 days after the herbicide application.

Results

The results of this experiment are presented in Table 13, which shows that there was complete control of Italian ryegrass and common chickweed at both rates of RH 315, 1 and 2 lb/A, and with all treatments. No control of composites was detectable.

Some differential response on henbit and crucifers was observed

Table 13. The effects of four types of irrigation management on the herbicidal action of two rates of RH 315. Experiment VII.

RH 315 lb ai/A	Soil moisture irrigation management	Percent chemical control[1]					
		Ryegrass	Chickweed	Shepherdspurse	Henbit	Bittercress	Composite[2]
1	Treatment applied on moist soil, sprinkler irrigation supplied immediately after application	100	100	70	70	60	0
2	" " "	100	100	100	100	100	0
1	Treatment applied on soil with optimum moisture, sprinkler irrigation supplied immediately after herbicide application	100	100	95	95	80	0
2	" " "	100	100	100	100	100	0
1	Treatment applied on moist soil, sprinkler irrigation supplied 40 hours after herbicide application	100	100	45	50	40	0
2	" " "	100	100	98	98	95	0
1	Treatment applied on soil with optimum moisture, sprinkler irrigation supplied 50 hours after herbicide application	100	100	30	60	40	0
2	" " "	100	100	100	100	100	0

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] Composites were: mayweed, prickly lettuce, groundsel, annual sowthistle, and spiny sowthistle.

between the two levels of soil moisture for RH 315 at 1 lb/A with sprinkler irrigation being supplied immediately after application; the treatment applied on moist soil gave less control of shepherdspurse henbit and bitter cress than that applied on a soil with optimum moisture. Noticeable difference appeared between the two types of irrigation management when the herbicide response on henbit and crucifers is considered for RH 315 at 1 lb/A; a 50-hour delay in supplying sprinkler irrigation caused 37% loss of herbicidal activity on henbit, 50% on bitter cress, and 68% on shepherdspurse, when RH 315 at 1 lb/A was applied on soil with optimum moisture. No differences were observed between treatments when RH 315 was applied at the rate of 2 lb/A.

Experiment VIII. Performance of RH 315 in Pre- and Post-Emergence Treatments Compared with Nitroanilines in Late Summer and Early Fall in a Silty Clay Loam Soil, and in a Sandy Loam Soil

This experiment was aimed at determining the herbicide response on weeds and lettuce under the conditions of the late summer and early fall. The postemergence and preemergence activity of RH 315 were also compared.

Materials and Methods

These experiments were conducted in the same manner as described in Experiment III, except that sprinkler irrigation was supplied immediately after the preemergence treatments were applied. In addition, postemergence treatments were included. These were applied when weeds were between one and three inches tall, and most of them had two true leaves or less.

Incorporation of nitroanilines (trifluralin, benefin and EL 179) was performed with a tractor-powered rotary tiller, but at low speed due to mechanical difficulties.

Results

The stand of lettuce was similar in all treatments and no deleterious effects were observed, either in the silty clay loam or the sandy loam.

The results of the experiment carried out in the silty clay loam are presented in Table 14, which show that the control with RH 315 both in pre- and postemergence treatments was excellent on most weeds present. There was no effect on composite weeds, but some reduction of growth was observed on these weeds with the postemergence treatments.

Nitroanilines provided no control of composite and cruciferous weeds. Italian ryegrass, lambsquarters, and pigweed were controlled by trifluralin and benefin as well as with RH 315. EL 179 appeared to be less effective; however, the control of these species was

Table 14. Effects of herbicides on the control of various weeds in a silty clay loam soil. Experiment VIII.

Treatment	ai lb/A	Type of application[2]	Percent chemical control[1]						
			Chickweed	Ryegrass	Black Mustard	Lambsquarters	Pigweed	Shepherdspurse & Bittercress	Composite[3]
RH 315	2.0	PRE	100	100	95	100	95	100	0
RH 315	2.5	"	100	100	100	100	99	100	0
RH 315	3.0	"	100	100	100	100	100	100	0
RH 315	2.0	POST	100	95	95	95	-[4]	100	10
RH 315	3.0	"	100	100	95	98	-[4]	100	10
RH 315	4.0	"	100	100	100	100	-[4]	100	20
Trifluralin	0.75	PPI	90	100	0	100	95	0	0
Benefin	1.25	"	75	98	0	100	95	0	0
EL 179	1.25	"	60	90	0	95	90	0	0
Check[5]	-	-	(181)	(479)	(15)	(20)	(1,280)	(38)	(82)

[1] Evaluation by visual rating: 0 = no effect, 100 = complete kill.

[2] PRE = preemergence treatments; POST = postemergence treatments made when weed seedlings had two true leaves or less; PPI = preplant soil incorporated treatments.

[3] The composites were: annual sowthistle, spiny sowthistle, groundsel, prickly lettuce, and mayweed.

[4] Pigweed was not present at the time of evaluation because killed by frost.

[5] $Weeds/m^2$ (Two months after this observation was made, the dominant weed was annual ryegrass)

satisfactory. The nitroanilines, particularly benefin and EL 179, appeared to be less effective on common chickweed than RH 315 under the conditions of this experiment.

The postemergence application of RH 315 did not affect lettuce even at the rate of 4 lb/A. The first symptoms on Italian ryegrass and chickweed appeared three days after the postemergence application of RH 315; pigweed showed no effect at this time. After six days, intense chlorosis and some wilting appeared on ryegrass and chickweed; pigweed began to show some yellowing. Seventeen days after application, ryegrass, chickweed, henbit, bitter cress, lambsquarters, shepherdspurse, and black mustard were completely killed at the rate of 4 lb/A, and almost so at the lower rates. Pigweed was killed by a light frost early in October, consequently the performance of RH 315 in postemergence application could not be determined on this species.

The results of the experiment carried out in the sandy loam soil are presented in Table 15. They show that ryegrass and chickweed were completely controlled by RH 315 at 1 lb/A either in pre- or postemergence application. Good control was also achieved with trifluralin, benefin and EL 179, the latter being somewhat less effective on ryegrass. Good control of pigweed and shepherdspurse was achieved with RH 315 at 1.5 lb/A in preemergence application. At 1 lb/A in postemergence application RH 315 completely controlled

Table 15. Effects of herbicides on the control of various weeds in a sandy loam soil. Experiment VIII.

Treatment	ai lb/A	Type of application[2]	Percent chemical control[1]				
			Ryegrass	Chickweed	Pigweed	Shepherdspurse	Composite[3]
RH 315	1.0	PRE	100	100	85	80	0
RH 315	1.5	"	100	100	95	95	0
RH 315	2.0	"	100	100	100	100	0
RH 315	1.0	POST	100	100	-[4]	100	0
Trifluralin	0.75	PPI	95	100	100	0	0
Benefin	1.0	"	95	95	95	0	0
EL 179	1.0	"	90	95	95	0	0
Check[5]	-	-	(428)	(87)	(776)	(27)	(65)

[1] Evaluation visual rating: 0 = no effect, 100 = complete kill.

[2] PRE = preemergence treatments; POST = postemergence treatments made when weed seedlings had two true leaves or less; PPI = preplant soil incorporated treatments.

[3] The composites were: annual sowthistle, spiny sowthistle, groundsel, prickly lettuce, and mayweed.

[4] Pigweed was not present at the time of evaluation because killed by frost.

[5] Weeds/m^2 (Two months after this observation was made, annual ryegrass was the dominant weed).

shepherdspurse. The nitroanilines gave good control of pigweed but no control of sheperdspurse.

None of the herbicides tested showed any action on composite weeds.

DISCUSSION AND CONCLUSIONS

The ideal herbicide, if it existed, would control all species of weeds without any harmful effect on the crop under any conditions. So far, this panacea has not been achieved. Therefore, the control of weeds in a given crop must be implemented with the use of more than one chemical and complemented with vegetation management, rotation, and other methods. The control of weeds in lettuce is a good example of the necessity for a combination of cultural practices.

Agamalian et al. (1967), and Lyons (1967), summarized the results of several trials carried out in a number of locations in California. From their reports it is apparent that not all of the weeds that are common in lettuce are controlled by a single herbicide.

Chemicals are being sought which are effective under different environmental conditions, soil types, and predominant weed populations. Furthermore, the extensive or repeated use of what was once a good herbicide may lead to important changes in the weed population which call for new materials that can take care of the modified situation. In the search for new chemicals, RH 315 has appeared promising in some respects.

The results of experiments carried out under greenhouse conditions proved that lettuce (Great Lakes type) tolerated RH 315 at 5.4 lb/A both in a silty clay loam and a muck soil. On the other hand, the same rate in a sandy soil caused a 40% reduction in the fresh weight of lettuce when measured 65 days after planting, whereas a rate of 2.7 lb/A was tolerated. Consequently, soil type strongly influenced the tolerance of lettuce to RH 315.

Figure 1 suggests that in the muck soil and the silty clay loam even higher rates of RH 315 may be tolerated. The results presented in Table 2 show that lettuce was not affected noticeably even at the rate of 8.1 lb/A in a medium textured soil.

Figures 2, 3 and 4 indicate that lettuce exhibited maximal growth depression due to RH 315 action during the early stages, about 40 days after planting. Any observation at this stage could be misleading if not complemented with a later evaluation. On the other hand, environmental stresses acting at these early stages of lettuce growth may lower the tolerance to the herbicide and cause irreparable injury to the crop. It seems that favorable conditions for growth facilitate the recovery from the biochemical pressure imposed by preemergence herbicides (Menges and Hubbard, 1967).

The results of experiments conducted under field contitions in late spring and early summer showed that lettuce tolerated RH 315 at 5 lb/A both in the silty clay loam and sandy loam without affecting the yield measured as fresh weight at the usual harvest time. However, later experiments in the summer showed that some stunting occurred in lettuce with RH 315 at 4 lb/A in the sandy loam, and at

5 lb/A in the silty clay loam. When these rates were doubled, an important reduction in stand and growth was observed, especially in the sandy soil.

A significant difference was observed between the lettuce grown from the coated seed and that from the bare seed. The greater tolerance in the latter may be tentatively attributed to a dilution effect, since the bare seed was planted at a much higher density than the coated seed. Consequently, many more lettuce seedlings were subjected to the same amount of chemical in the case of the bare seed than with the coated seed.

In general, the performance of RH 315 in controlling weeds has ranged from fair to excellent. These fluctuating or erratic results seem to be due to different environmental conditions, mainly temperature and the amount of moisture after application.

By examining the results from the various experiments, it may be concluded that the greater the delay in supplying overhead moisture to the soil after application, the greater the loss of activity. The latter is further accentuated if the application of RH 315 is made on moist soil.

The effect of the air and soil temperature was not evaluated directly. However, by comparing the performance of RH 315 in different experiments carried out through the season it is possible tentatively to infer that RH 315 is more active in controlling certain weeds at lower temperatures. Table 16 shows this tendency although these results do not constitute conclusive evidence. However, a technical bulletin from Rohm and Haas Company[6] reports that RH 315 is most stable at low temperatures, and it is generally most effective when applied in the fall or early spring. On the other hand, it remains to be determined whether the lettuce tolerance will be affected in the same manner.

The results from the experiments carried out in the greenhouse and in the field show that RH 315 was highly effective in preemergence applications on all the grasses that were present in the experiments, namely, annual bluegrass, barnyardgrass, Italian ryegrass and green foxtail. It was also highly effective on common chickweed, purslane, mouseear chickweed, lambsquarters, henbit, red deadnettle, shepherdspurse, and bittercress. The foregoing species were controlled with rates of 1.5 to 2 lb/A in the silty clay loam, and 1 to 1.5 lb/A in the sandy loam, the lower rates being effective with average temperature below 60 F and enough moisture following application to activate the compound. These results mostly confirm those obtained by Agamalian and Lange (1969).

The control of pigweed required higher rates of RH 315 and was

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[6]Kerb Selective Experimental Herbicide (RH 315), Technical Bulletin. Rohm and Haas Company, Independence Mall West, Philadelphia, Pennsylvania 19105.

Table 16. Performance of RH 315 on pigweed and mustard in preemergence application in different seasons.

Season	Average temperature[1] °F	Evaporation[2] inches	Percent chemical control of pigweed[3]: Sandy loam, RH 315: lb/A				Silty clay loam, RH 315: lb/A					
			1.0	1.5	2.0	3.0	1.5	2.0	2.5	3.0	3.5	5.0
Early summer	65	1.67	-	81	-	97	20[a]	-	-	31[a]	-	87[a]
Middle summer	61	1.66	74	94	100	-	40	-	76	-	91	100
Early fall	59	0.86	85	95	100	-	-	95	99	100	-	-

Season	Average temperature[1] °F	Evaporation[2] inches	Percent chemical control of wild mustard[3]: Sandy loam, RH 315: lb/A						Silty clay loam, RH 315: lb/A				
			1.0	1.5	2.0	3.0	4.0	5.0	1.5	2.5	3.0	3.5	5.0
Early summer	65	1.67	-	65	-	88	-	99	5[a]	-	12[a]	-	62[a]
Middle summer	61	1.66	18	63	91	-	100	-	10	62	-	85	90

[1] Average temperature of the week following application.

[2] Evaporation, total of the week following application.

[3] Subjective evaluation by visual rating: 0 = no effect, 100 = complete kill.

a = This treatment was applied on moist soil. Sprinkler irrigation was supplied for the first time five days after the preemergence application.

more dependent on environmental conditions. Good control was achieved at 2.5 to 3.5 lb/A in the silty clay loam, and 1.5 to 2 lb/A in the sandy loam. Wild mustard appeared to be more tolerant to RH 315 than pigweed and good control was not achieved with rates of probable commercial use.

The postemergence activity of RH 315 was tested during the summer (results not reported elsewhere) on purslane, groundsel, and pigweed. The application was made when most of the weeds had four to six true leaves. There was no appreciable effect on any weed at the rate of 2.5 lb/A, which was the highest dosage of RH 315 tested. However, when this compound was applied on weeds at earlier stages, two true leaves or before, in early fall, it appeared to possess very good activity. It controlled susceptible weeds at about the same rates that were effective in preemergence applications under the same conditions, that is, temperature below 60 F and adequate moisture. Between 17 to 20 days were required for RH 315 to exert its effect on some weeds such as Italian ryegrass, henbit, common chickweed, and lambsquarters at 2 lb/A in the silty clay loam, and 1 lb/A in the sandy loam with some of the same weeds.

The experiments on the residual action of RH 315 show that the quantities which control weeds suceptible to this compound were dissipated 60 days after application under summer conditions to levels which did not affect the emergence and growth of any vegetable tested:

snap beans, sweet corn, cucumbers, and red beets. Moreover, two susceptible weeds, annual bluegrass and common chickweed were present and not affected. At higher rates, 3.5 lb/A or more in the silty clay loam and 2 lb/A or more in the sandy loam, the residue remaining 60 days after application caused injury to those vegetables in proportion to the rates applied. The most susceptible species were red beets and cucumbers, the least affected were snap beans, with sweet corn being intermediate.

Trifluralin at 0.75 lb/A gave excellent control of Italian ryegrass, barnyardgrass, pigweed, and purslane, both in the silty clay loam and sandy loam. Benefin and EL 179, both at 1 lb/A, gave good control of the foregoing weeds in the silty clay loam. Benefin at 0.75 lb/A did not perform as well in the sandy soil.

Delaying incorporation until 68 hours after application caused a 70% loss of trifluralin activity and a 35% loss of benefin action. This difference may be attributed to the fact that trifluralin possesses a much higher vapor pressure (1.99×10^{-4} mm Hg at 29.5 C) than benefin (4×10^{-7} mm Hg at 25 C).

The residue remaining from trifluralin treatment with 0.75 lb/A 82 days after application caused considerable injury to sweet corn, red beets and cucumbers, but no effect on snap beans. It also brought about a 75% reduction of growth on common chickweed. The results were similar in both types of soil.

In the experiment carried out in the silty clay loam, the residue remaining from EL 179 and benefin treatments, both at 1 lb/A, 82 days after application, caused only little damage to sweet corn, red beets, and cucumbers, but no effect on snap beans and common chickweed. Similar results were observed with benefin at 0.75 lb/A in the sandy loam.

Bensulide at 6 lb/A preplant incorporated and CDEC at 5 lb/A in preemergence were tested only in the silty clay loam. The former gave poor weed control in general, but the latter performed very well on pigweed, Italian ryegrass, and barnyardgrass.

The residue remaining from bensulide treatment at 6 lb/A 82 days after application caused considerable injury only to sweet corn, but no effect on snap beans, cucumbers, and red beets. The residue from CDEC at 5 lb/A 60 days after application did not affect any of the preceding vegetables.

In conclusion, the results of these experiments demonstrated that RH 315 is effective for selective control of many weeds in lettuce, some of them not controlled by standard herbicides. In addition, its biological residual life appeared to be short enough to allow the cropping of susceptible vegetable species soon after the harvest of the lettuce crop treated with this compound under summer conditions.

Finally, the preemergence activity of RH 315 appears to be dependent on the supply of moisture immediately after application, especially under conditions of high temperature and high rate of evaporation.

SUMMARY

Greenhouse and field experiments were conducted to determine the tolerance of lettuce to N-(1, 1-dimethylpropynyl)-3, 5-dichlorobenzamide (RH 315) in three types of soil. Its performance on weeds under different environmental conditions, its residual action on other vegetables, as well as pre- and postemergence activity on weeds were also tested. Other herbicides were used in some experiments.

The results obtained are summarized as follows:

1. Lettuce of the crisphead type appeared to possess high tolerance to RH 315 to the extent that a safety factor greater than 2 X is provided when susceptible weeds are considered.
2. The tolerance was greater in a silty clay loam and a muck soil than in a sandy soil. As the performance on weeds was also affected by the type of soil, the safety factor does not necessarily vary with tolerance.
3. There was variation in the degree of tolerance between experiments carried out in the greenhouse and those conducted in the field. Tolerance also varied with season in field experiments. It is possible to conclude that some environmental conditions might act as stresses on lettuce growth and reduce its tolerance.

4. RH 315 at rates of 1.5 to 2 lb/A in a silty clay loam and at 1 to 1.5 lb/A in a sandy loam effectively controlled annual bluegrass, Italian ryegrass, common chickweed, purslane, mouseear chickweed, lambsquarters, henbit, red deadnettle, shepherdspurse and bittercress. The control of pigweed and wild mustard required higher rates.

5. The preemergence activity of RH 315 appeared to be dependent on the supply of moisture immediately after application. Delaying sprinkler irrigation after application caused reduction of RH 315 activity.

6. RH 315 appeared to be more effective in controlling weeds in early fall than during the summer. In the first case the average temperature of the week following application was below 60 F, whereas in the latter case it was about 65 F. There was also difference in the amount of evaporation for the same period.

7. The residues of RH 315 from rates which were effective in controlling susceptible weeds, caused no injury on snap beans, sweet corn, cucumbers, red beets, common chickweed and annual bluegrass when tested 60 days after application under summer conditions. The foregoing species appeared to be susceptible to RH 315 in preemergence treatments except for snap beans which proved to possess

some tolerance.

8. RH 315 proved to possess postemergence activity when applied on susceptible weeds at the early stage of growth, that is, two true leaves or before. Between 17 to 20 days were required for RH 315 to exert its effect on some weeds such as Italian ryegrass, henbit, common chickweed and lambsquarters at 2 lb/A in the silty clay loam, and 1 lb/A in the sandy loam, both under conditions of early fall.

9. Trifluralin at 0.75 lb/A provided excellent control of Italian ryegrass, barnyardgrass, pigweed and purslane both in the silty clay loam and sandy loam. Benefin and EL 179 both at 1 lb/A gave good control of the foregoing weeds in the silty clay loam, but their performance was inferior to that of trifluralin. Benefin at 0.75 lb/A did not perform very well in the sandy loam.

10. Delaying incorporation 68 hours after application caused 70% loss of trifluralin activity and 35% loss of benefin action in the sandy loam.

11. The residual action of trifluralin, when tested by vegetable plant growth, was greater than that of EL 179 and benefin, 82 days after application. The least residual action was obtained with CDEC and RH 315 when tested 60 days after application.

12. Bensulide at 6 lb/A preplant soil incorporated and CDEC at 5 lb/A in preemergence application were tested only in the silty clay loam. The former gave poor control in general, but the latter performed very well on pigweed, Italian ryegrass and barnyardgrass. No residual effect was observed from CDEC, whereas bensulide residues 82 days after application caused considerable injury to sweet corn.

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APPENDICES

APPENDIX I

The principal weeds found in lettuce in California (Agamalian *et al.*, 1967):

Common purslane (*Portulaca oleracea* L.)

Pigweed (*Amaranthus* spp.)

Common lambsquarters (*Chenopodium album* L.)

Mustard (*Brassica* spp.)

London rocket (*Sisymbrium irio* L.)

Shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.)

Nightshade (*Solanum* spp.)

Burning nettle (*Urtica urens* L.)

Stinging nettle (*Urtica dioica* L.)

Common chickweed (*Stellaria media* (L.) Cyrill.)

Corn spurry (*Spergula arvensis* L.)

Mallow (*Malva* sp.)

Groundsel (*Senecio vulgaris* L.)

Barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.)

Annual bluegrass (*Poa annua* L.)

Volunteer barley (*Hordeum* sp.)

Canarygrass (*Phalaris canariensis* L.)

APPENDIX II

Principal weeds found in lettuce in Argentina.

I. In late spring and summer crops:

Common purslane (Portulaca oleracea L.)

Common lambsquarters (Chenopodium album L.)

Smooth pigweed (Amaranthus hybridus L.)

Barnyardgrass (Echinochloa crusgalli (L.) Beauv.)

Jungle rice (Echinochloa colonum (L.) Link)

Foxtail (Setaria sp.)

Large crabgrass (Digitaria sanguinalis (L.) Scop.)

Spurred anoda (Anoda cristata (L.) Schlecht)

II. In fall and winter crops:

Annual bluegrass (Poa annua L.)

Stinging nettle (Urtica dioica L.)

Shepherdspurse (Capsella bursa-pastoris (L.) Medic.)

Swine cress (Coronopus didymus (L.) Smith)

Mayweed (Anthemis cotula L.)

Smallflower galinsoga (Galinsoga parviflora Cav.)

Italian ryegrass (Lolium mutiflorum Lam.)

Common chickweed (Stellaria media (L.) Cyrill)

Prostrate knotweed (Polygonum aviculare L.)

APPENDIX III

The main weeds found in lettuce in Oregon:

Mayweed (*Anthemis cotula* L.)

Groundsel (*Senecio vulgaris* L.)

Nightshade (*Solanum* sp.)

Shepherdspurse (*Capsella bursa-pastoris* (L.) Medic.)

Common lambsquarters (*Chenopodium album* L.)

Pigweed (*Amaranthus* sp.)