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AN ABSTRACT OF THE THESIS OF

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Title: INTERACTIONS OF CYCLOATE WITH POSTEMERGENCE HERBICIDES ON SUGARBEETS AND WEEDS

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Dr. Arnold P. Appleby

Research was conducted to (a) quantitatively study under field conditions, the nature of interactions between S-ethyl N-ethylthio-cyclohexanecarbamate (cycloate) and postemergence herbicides on sugarbeets (*Beta vulgaris* L.) and several weed species and (b) determine in the laboratory if observed interactions are a result of cycloate's effect on leaf wax formation.

Synergism occurred with cycloate and postemergence herbicides according to Colby's (1967) method of calculating expected responses. Synergism occurred with cycloate plus 5-amino-4-chloro-2 phenyl-3 (2H)-pyridazinone,2,2-dichloropropionic acid (Pyramin Plus) or cycloate plus 3-methocycarbonylaminophenyl-N-(3'-methylphenyl) carbamate (phenmedipham) combinations under field conditions. Rates of cycloate preplant incorporated at .25, .50, 1, 2, 4, and 6 and postemergence treatments of Pyramin Plus

at 9 and 12 are phenmedipham at 1, 2, and 6 lbs. a.i./A were used alone and in combination. Control of redroot pigweed (Amaranthus retroflexus L.), common mustard (Brassica compestris L.), common groundsel (Senecio vulgaris L.), lambsquarters (Chenopodium album L.), and barnyardgrass (Echinochloa crusgalli L. Beauv.) was generally better with the combinations than with any of the herbicides used alone.

Laboratory studies showed that cycloate caused a highly significant reduction of surface wax on cabbage leaves. There was no significant effect on surface wax of sugarbeets, pigweed, and mustard leaves. The amount of surface wax on leaves of these three species was much less than for cabbage. Perhaps the method of analysis was not sensitive enough to measure a response.

Scanning electron micrographs of sugarbeets, pigweed, and barnyardgrass showed some morphological effects on the leaf surface from cycloate treatments. Cycloate appeared to produce a "cracking" effect on sugarbeet and pigweed cuticle which is indicative of surface wax loss or reduction (Mueller, 1954). The micrographs indicated that the stomata of pigweed treated with cycloate remained closed while the stomata of untreated pigweed remained open. In both the untreated and cycloate-treated sugarbeet leaves the stomata remained open. Cycloate also produced an apparent reduction in the number of wax rodlets in barnyardgrass leaves.

The results showed quantitatively that combinations of cycloate and postemergence herbicides had a synergistic effect on phytotoxicity to several weed species. Laboratory experiments indicated that through the "cracking" effect on broadleaf plant leaf surfaces and a reduction in number of wax rodlets in barnyardgrass, at least part of the synergistic effects measured in the field may be explained by a cycloate-induced increase in uptake or utilization by weed species of postemergence herbicides.

Interaction of Cycloate with Postemergence Herbicides on Sugarbeets and Weeds

by

Phillip David Leroy Olson

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INTRODUCTION

Cycloate is a soil-active herbicide belonging to the thiolcarbamate family. It is used selectively in sugarbeets as a preplant treatment for the control of grass weeds and some broadleaves. It is usually applied as a band treatment and incorporated with a power rototiller or injected directly into the soil next to the seeded sugarbeet row.

Cycloate has a definite weakness on certain broadleaf weeds and is often supplemented with a herbicide applied postemergence. Pyramin Plus or phenmedipham is often used as the supplemental postemergence herbicide.

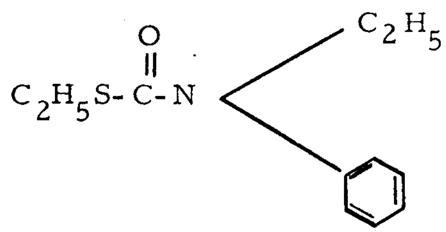
Combinations of cycloate with postemergence herbicides have been observed to increase total weed control. Weeds surviving the cycloate treatment have appeared to be more susceptible than untreated weeds to herbicides applied postemergence. Reasons are not known as to why cycloate increases apparent sensitivity of weeds to subsequent postemergence herbicides. However, certain thiolcarbamates have been reported to reduce cuticular wax formation. Gentner (1966) and Wilkinson and Hardcastle (1969) have shown that EPTC can reduce wax formation in certain plant species. This reduction of surface wax could facilitate easier penetration or absorption of post-emergence herbicides.

The objectives of this thesis were (a) to study the nature of interactions between cycloate and postemergence herbicides on sugar-beets and several weeds including quantitative estimates of such interactions and (b) to measure the effect of cycloate on cuticular wax by means of chemical analysis and electron microscope studies.

LITERATURE REVIEW

Properties of Cycloate

The chemical name and structure for cycloate is as follows:



S-ethyl N-ethylthiocyclohexanecarbamate

Cycloate is in the thiocarbamate herbicide family. The technical form of cycloate is a liquid. Its solubility in water is 100 ppm. It is miscible in most organic solvents. The pure chemical has a boiling point at 145-146 C at 10 mm of mercury. Its vapor pressure is 2×10^{-3} mm of Hg at 25 C. Other details of the physical, chemical, and toxicological properties of cycloate can be found in the cycloate technical bulletin printed by Stauffer Chemical Company.[1]

Because of its high vapor pressure, cycloate requires mixing or incorporation into the soil to prevent it from volatilizing into the atmosphere and losing its herbicidal potential. The formulations of

[1] Ro-Neet Herbicide Technical Bulletin. Stauffer Chemical Company. Agricultural Research Center, P. O. Box 760, Mountain View, California.

cycloate available for commercial use are an emulsifiable concentrate containing six pounds of active ingredient per gallon and a granular formulation containing 10% cycloate by weight.

The herbicidal mechanism of cycloate or any of the other thiocarbamates is not clearly understood. Foy and Penner (1965) found that EPTC (S-ethyl dipropylthiocarbamate) inhibited oxidative phosphorylation of cucumber mitrochondria at high concentrations. The physiological significance is questionable because of the excessive rates of EPTC used. Researchers have speculated that the thiocarbamates may inhibit mitosis but this has not been proven conclusively. James *et al*. (1970) found that induced elongation of soybean hypocotyl sections by three growth regulators, 2,4-D, dicamba, and picloram, was inhibited in the presence of EPTC. Similarly, curvature tests using soybean hypocotyl sections showed the curvature induced by the growth regulators to be almost completely eliminated by the presence of EPTC.

Cycloate has been used successfully as a selective herbicide in sugarbeets, table beets, and spinach for the control of most annual grasses such as barnyardgrass (*Echinochloa* spp.), annual ryegrass (*Lolium multiflorum* L.), crabgrass (*Digitaria* spp.), and wild oats (*Avena fatua* L.). Perennial grasses controlled by cycloate are yellow nutsedge (*Cyperus esculentus* L.), and purple nutsedge (*Cyperus rotundus* L.). Cycloate is weak on several annual broadleaf weeds such as pigweed (*Amaranthus* spp.), mustard (*Brassica* spp.), and lambsquarters (*Chenopodium album* L.).

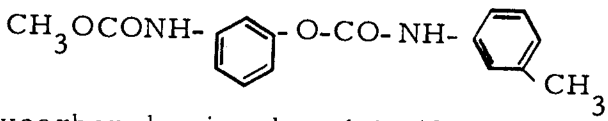
A second herbicide is often used in combination with cycloate to control broadleaf weeds. Research conducted at Oregon State University and work reported by Lee *et al*. (1969) has repeatedly shown that better weed control can be achieved in sugarbeets if cycloate is used in combination with a selective postemergence herbicide. Commercial applicators and sugarbeet growers use postemergence herbicides with cycloate for better total weed control. Often, these herbicides used in combination work much better together than when used alone. Linscott and Hagin (1967) reported similar activities in alfalfa and birdsfoot trefoil with EPTC preplant incorporated followed with a postemergence treatment of dinoseb.

Postemergence Herbicides Used with Cycloate

Herbicides that have been used commercially postemergence in combination with cycloate are phenmedipham and Pyramin Plus. Both of these herbicides have broadleaf and grass phytotoxicity with some weaknesses.

Phenmedipham

The chemical name and structure for phenmedipham is as follows:



3-methoxycarbonylaminophenyl-N-(3'-methyl) phenyl carbamate

The appearance of the technical form of phenmedipham is a colorless crystalline substance. The solubility of phenmedipham in water is $<$ 10 mg/L. The formulation of phenmedipham available for commercial use is an emulsifiable concentrate containing 16.5% w/w active ingredient. Other properties of phenmedipham are summarized in a phenmedipham information bulletin from Schering AG.[2]

Phenmedipham is applied as a postemergence treatment. It is absorbed through the foliar portion of the plant. It has no soil activity at recommended rates. Phenmedipham is used selectively in sugar-beets, fodder beets, and table beets. Annual weeds commonly found in sugarbeets that are controlled by phenmedipham include lambs-quarters, wild buckwheat (*Polygonum convolvulus* L.), green and yellow foxtail (*Setaria viridis* L.) and (*S. glauca* L.), mustards, nightshades (Solanum spp.), prostrate pigweed (*Amaranthus graecizans* L.), and kochia (*Kochia scoparia* L.). Annual weeds that phenmedipham is weak on are redroot pigweed (*Amaranthus retro-flexus* L.) and barnyardgrass (*Echinochloa crusgalli* L.).

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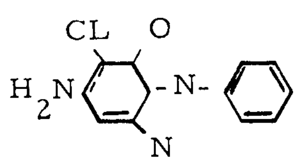
[2] Betanal Second Information Bulletin. Schering A.G. Berlin 65. Postfach 59.

It has been observed in recent studies at Oregon State University that the phytotoxic activity of phenmedipham is enhanced when used in combination with cycloate. When used with cycloate, phenmedipham often will control pigweed and other weeds that it will not control when applied alone.

Pyramin Plus

Pyramin Plus is a commercial formulation of pyrazon and dalapon with wetting agent added. The formulation contains 27% pyrazon and 21.2% dalapon and is sold commercially as a wettable powder.

The physical and chemical properties of pyrazon is summarized in the Herbicide Handbook of the Weed Society of America[3], pp. 5-8. The chemical name and structure for pyrazon are as follows:

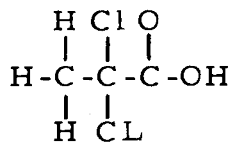


5-amino-4-chloro-2-phenyl-3(2H)-pyridazinone

The physical state of the technical form of pyrazon is a tan-brown powder. The solubility of pyrazon in water at 20 C is 0.03 g/100 g.

[3] Herbicide Handbook of the Weed Society of America. 1970. W. F. Humphrey Press. 368 p.

The physical and chemical properties of dalapon are summarized in the Herbicide Handbook of the Weed Society of America[3], pp. 180-183. The chemical name and structure for dalapon are as follows:



2,2-dichloroproponic acid

The technical form of dalapon is a colorless liquid that is very soluble in water. In Pyramin Plus, dalapon is in the form of a sodium salt.

Pyramin Plus is used as a selective herbicide in sugarbeets. When used in combination with cycloate it has been observed at Oregon State University and by Lee *et al*. (1969) that the weed control activity of the postemergence material is increased. Common weeds controlled in sugarbeets by Pyramin Plus are lambsquarters, pig-weed, nightshade, mustard, foxtail, and barnyardgrass.

Pyramin Plus is absorbed through the foliar portion of the plants. The material also has some residual activity.

Structure and Formation of Cuticle

The first barrier encountered in the penetration and adsorption of a herbicide is the outer waxy layer of the epidermis called the cuticle. The cuticular layer is found on stems, leaves, and other above-ground exposed parts of plants.

The structure of the cuticle is of particular interest to herbicide investigators who are concerned with the penetration of foliage-applied herbicides. The chemical structure of the cuticle is made up of four major components: cutin, waxes, pectin, and cellulose. Cutin is a semi-lipoidal oxidative polymer of long-chained fatty acids and alcohols and is semipolar. Cuticular wax refers to the petroleum ether-soluble mixture of more saturated lipid substances embedded in the cuticular layers. Pectin consists of long-chained polygalacturonic acid molecules having side carboxyl groups and is polar. Cellulose is composed of long-chained molecules associated into microfibrils and is polar in nature (Foy et al., 1967).

The physical structure of the cuticle is well illustrated in a sub-microscopic drawing from Orgell (1954) (Figure 1). The surface is made up of a wax layer consisting of wax rodlets or bloom in a variety of patterns (Mueller et al., 1954). Beneath the surface waxy layer is a layering of wax lamellae, cutin, and cellulose lamellae. A layer of pectic lamellae lies next to the epidermal cell wall which is cellulose in nature.

The source and mode of migration of cuticular components from the epidermal cells is still unclear. Schieferstein and Loomis (1959) visualize an initial flooding of the outer surface of the epidermis

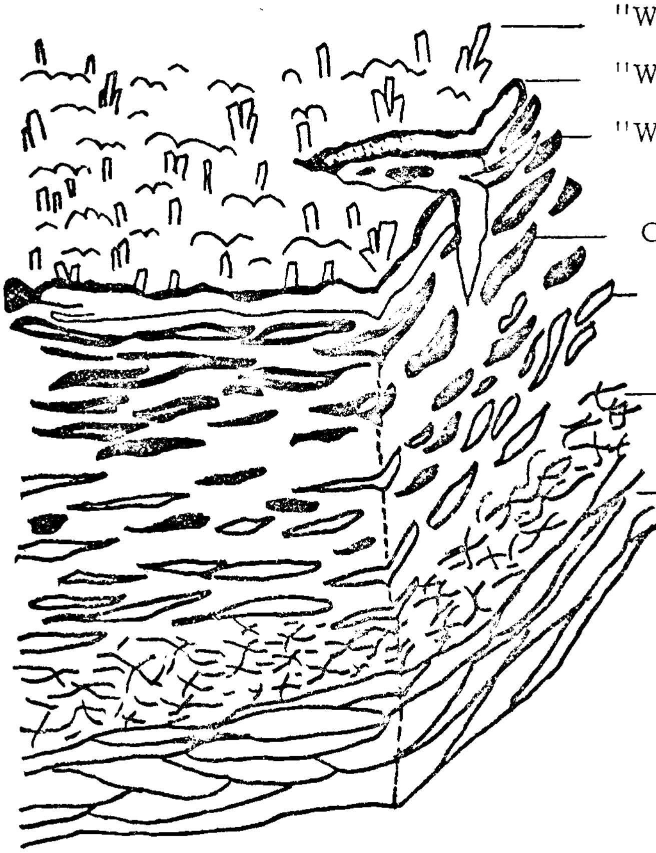


Figure 1. Submicroscopic structure of the cuticle. From Orgell (1954).

with a substance resembling a drying and hardening oil. Under this primary cuticle further cuticular layers, containing a mixture of cutin, waxes, and other materials, may be deposited and produce thick, sometimes laminated cuticles. As the cutin and waxes migrate through the outer wall toward the surface they also impregnate this wall. Esau (1960) feels that the presence of plasmodesmata may play an important role in the migration of the cutin and waxes from the epidermal cells. Kolattukudy (1968) found by using labeled acetate that the elongation of fatty acids followed by decarboxylation is the most likely pathway for wax biosynthesis in leaves. The work suggested that the epidermis is the site of synthesis of both waxes and long-chained fatty acids. Skoss (1955) postulated that wax is formed in the living epidermal cell and is passed to the surface through micro-passages present in the outer walls of the cell and there hardens to dry wax lamellae and/or granules.

Wax formation begins when the leaves are very young (Juniper, 1960) and increases as the leaf grows older (van Overbeek, 1956). Formation appears to be limited to young or growing leaves (Schieferstein and Loomis, 1959). This formation begins before the leaf unfolds (Juniper, 1960).

Environmental factors often play an important role in wax and cuticular formation. In studies by Juniper (1960) increased wax bloom was directly correlated to increase in light intensity. Skoss (1955) found that leaves exposed to direct sunlight have a heavier wax content. Other factors presented by Skoss (1955) that increases the amount of wax deposit on plant leaves are high temperatures and water stress. Hull (1958) found that in velvet mesquite total wax content was highest in plants grown at high temperatures--both day and night.

The amount of wax on leaves differs with different plant species. Kurtz (1950) collected 13 species of plants from several plant families. He found that the relationship of wax yield to plant age varied with different species.

Microscopic Studies of Cuticular Surface

Leaf surfaces have been studied through the microscope since the sixteenth century. Recent studies of the cuticle and its surface using electron microscope techniques have revealed some interesting aspects of surface structure. There have been many workers involved in surface studies including Eglington et al. (1967), Norris (1968), Foy (1964), Franke (1967), Mueller et al. (1954), and Scott et al. (1958). The cuticle as a whole is a uniform membrane with no surface holes or pores, just cracks due to the environment. The cuticle waxy surface is more or less continuous but irregular and nonuniform as to surface relief. Lange (1969) demonstrated that the outer surface of the cuticle may exhibit systems of concavities and convexities of the same scale and in the same pattern as the underlying epidermal cells.

Secondly, the outer surface may exhibit independent microrelief. Typically this is on a much smaller scale than the first-order relief, ranging from smooth through degrees and varieties of granulations.

Bystrom et al. (1968) studied the leaf surface of sugarbeet leaves of different ages with a light microscope. Examinations of the leaf surface of a very young leaf showed that the wax occurs in the form of stubby rodlets. As leaf growth progresses the extrusion of the rodlets continues and they coalesce to form plaques. In young-mature leaves central wax plaque is surrounded by peripheral rodlets. By full maturity the entire surface is covered. As the extrusion rate slows in aging leaves, the waxy surface becomes fatter and smoother. In contrast to the results of Bystrom et al. (1968), Eglington et al. (1967) has shown leaf surfaces of sugarbeets with no "apparent surface wax".

Schieferstein and Loomis (1959) studied the well-developed cuticle of cabbage (Brassica oleracea L.) using an electron microscope. Abundant deposits of surface wax were observed on leaves less than 1 cm in diameter. In cross sections the waxy portion of the cuticle made up about 2% of the total thickness of the epidermal wall and is underlain by pectic layer about twice as thick as the above cuticle. The wax on the surface of cabbage leaves has a characteristic reticulate or semicrystalline form. Occasionally many fine threads of wax fuse to form rodlets.

The amount and degree of roughness of surface wax deposits on the cuticule surface affect spray retention and contact angle of spray droplets (Dewey *et al.*, 1956; van Overbeek, 1956; Silva Franandes, 1965). Ebeling (1939) found that leaves of different species, different age of plant, and different sides or portions of a single leaf caused variations in the contact angle of a droplet.

Environmental factors such as wind by itself, wind with soil particles, and rain can cause reduction in surface wax (Dewey *et al.*, 1956). Dewey *et al.* (1956) found this to be true in sugarbeets. Hall and Jones (1961) observed the effects of wind on the leaf surface of New Zealand and Spanish white clovers (*Trifolium repens*). Their studies showed that weathering by wind would remove wax and lessen the angle of water droplet contact.

Penetration Through Leaf Surfaces

Many researchers have shown that chemicals may enter the leaf through the stomata and/or directly through the cuticle. Opinion is divided as to whether stomatal or cuticular entry is more important.

Stomata

Conflicting evidence has been presented in the literature as to the role of stomata in leaf uptake. A great deal of research has shown that the stomata are a very important route in the penetration of uptake of chemicals. Dybing (1958) using a Prussian-blue precipitation method in Zebrina found that the ferric iron from $Fe_2(SO_4)_3$ solutions penetrated the leaf readily by the stomata, especially when a surfactant was employed. Dybing and Currier (1959) later used a fluorescent dye method and when a suitable surfactant was employed, entry by open stomata was very rapid and the leaves became intensely stained in 30 seconds. Aslander (1927) noted that the mesophyll cells in the immediate vicinity of the stomata were first to be destroyed by a caustic herbicide. Foy (1962a) in studying patterns of absorption of labeled dalapon in Tradescantia flumenensis found that the dalapon was absorbed through open stomata, clearly the most expeditious route of entry. Malisauskiene (1964) reported that among 12 herbaceous and 12 woody species, a direct relationship existed between susceptibility to 2,4-D and both thinness of cuticle and number of open stomata. On the other hand, Fogg (1948) found that stomatal uptake of 3, 5 dinitro-o-cresal in Sinapsis leaves was unimportant. Uptake was totally cuticular.

There is usually more penetration through the stomata in the lower surface of a leaf than the upper surface. This is because of a larger number of stomata in the lower surface (Fuller and Tippo, 1955; Foy et al., 1967). High humidity, warm temperatures, and light are important for stomatal penetration (Foy et al., 1967).

After entry through the stomatal opening there is still the problem of internal absorption through the internal cuticle lining the stomata cavities (Franke, 1967; Foy, 1964). But the internal layer is thinner and there is less chance of spray solution drying down as on the leaf surface. Entry into the stomata is by mass movement and oils and aqueous solutions having lowered surface tensions from the addition of surfactants penetrate the stomata readily (Foy, 1964). Van Overbeek (1954) stated that aqueous solutions will not penetrate the stomata. Only liquids of low surface tension such as oils penetrate the stomata.

Cuticle

There is no doubt that the cuticle acts as a barrier to the movement of chemical molecules but penetration is possible. Foy (1962) found in tracer studies using labeled dalapon that the herbicide penetrated the leaves of *Tradescontia flumenensis* and penetration was enhanced by surfactants. Dybing (1958) later confirmed cuticle penetration with fluorescent dye. Yamada (1964) made an excellent study of cuticular penetration using radioactive cations and anions. He used isolated cuticles of tomato fruit having no stomata openings and penetration through the cuticle was clearly evident. Foy *et al.* (1967) used a histoautiography method of tracing to study penetration of TBA, 2,4-D, monuron, amiben, silvex, and some triazines. All of these herbicides penetrated the cuticle. Most of the findings reported in the literature agreed that cuticular penetration was by diffusion. Both polar and apolar routes exist in the cuticle. Oils and aqueous (non-polar fat-soluble molecules and polar ions) will penetrate the cuticle.

Preferential areas of cuticular penetration of foliar adsorption are over the veins, anticlinal epidermal walls, and via hairs. Physical damage such as fissures, insect punctures, and imperfections in the cuticle are very important in foliar adsorption. Cuticle thickness is also very important. The thinner the cuticle, the more cuticular penetration (Norris, 1968; Hoehne, 1950; Malisauskiene, 1964).

Surfactants facilitate and accentuate both stomatal and cuticular penetration through emulsifying, dispersing, spreading, wetting, solubilizing, and/or other surface-modifying properties (Staniforth and Loomis, 1949; Darlington and Circulia, 1963; Currier and Dybing, 1959).

There have been recent postulations that ectodesmata are important in cuticular penetration (Foy, 1962; Franke, 1967). Franke (1967) defined them as fine structures in the outer wall of epidermal cells that extend through the cuticle and are interfibrillar spaces containing liquid excretion products from epidermal protoplasts.

Herbicidal Effect on Cuticular Formation

The possible reduction of wax in the cuticle because of herbicides was first reported by Dewey *et al.* (1956). They found that TCA and dalapon at rates as low as 1.5 lb a.i./A increased the wettability and probably permeability of the leaf surface of peas in the field. These herbicides increased pea susceptibility to dinoseb sprays. They found similar effects on Polygonum aviculare. They postulated that this effect was due to an interference with wax formation and excretion. Further experiments in the greenhouse by Dewey et al. (1956) graphically showed that as they increased the rate of dalapon and TCA from zero to 16 lb a.i./A, the effect of 2.3 lb a.i./A dinitro on peas was greatly enhanced from zero to 100%. Juniper (1959) studied the effect of TCA on peas. Peas sown in TCA-treated sand were affected in regard to the behavior of water droplets on the leaves. It was found that the angle made by the droplet on the surface decreased with increasing concentrations of TCA. Investigation with an electron-microscope on the surface of pea leaves treated with TCA revealed significant differences in the leaf surfaces in comparison to non-treated leaves. A reduction in the number and a change in form of the minute wax structures occurred with an increased concentration of TCA in the soil. Dewey et al. (1962) extracted wax from pea and kale leaves treated with TCA using cyclohexane. The extraction experiments showed a reduction of surface wax due to TCA.

Further work by Dewey et al. (1962) reflected the possibility that increased water retention on the leaves due to TCA is not the sole cause for greater susceptibility to postemergence herbicides.

Nettle, whose leaves are water receptive after TCA treatments, had no increased response to postemergence dinitro treatments.

Gentner (1966) found that EPTC and certain other thiolcarbamates can inhibit deposition of foliage wax on cabbage leaves. The inhibited deposition resulted in increased transpiration, increased spray retention, and decreased contact angle of spray droplets, as well as enhanced absorption of foliar-applied dinoseb. The work showed that if EPTC was originally applied as a spray, only leaves then in the bud were affected, whereas granules applied to the soil extended the period during which foliar wax of cabbage leaves was inhibited. Wilkinson and Hardcastle (1969) studied the effects of sicklepod (*Cassia obtusifolia* L.) after treatment with EPTC and found petiole cuticle thickness decreased 35% as herbicide concentration increased from zero to 4.48 kg/ha. Kolattukudy (1968) has suggested that fatty acid composition appears to influence the effect of EPTC on wax deposition. Wilkinson and Hardcastle (1969) go on to say that EPTC action appears to be primarily on the production of enzymes which control the production of lipids.

EFFECTS OF POSTEMERGENCE HERBICIDES IN THE FIELD ON SUGARBEETS AND WEED SPECIES PRE-TREATED WITH CYCLOATE - 1968

Methods and Materials

A preliminary field experiment was established at the East Agronomy Farm near Corvallis, Oregon on June 24, 1968. The objectives of the experiment were to determine if synergistic effects could be achieved on weedy plant species with certain cycloate-postemergence herbicide combinations and to determine if the same effects occurred on sugarbeets.

The soil type in the experiment was a Chehalis sandy loam with organic matter of 1.75%. Preplant incorporation treatments of cycloate were incorporated with a tractor-powered rototiller to a depth of three inches on June 24, 1968. Soil temperature was 75 F. Rates of cycloate included in the experiment were .25, .50, 1, 2, and 4 lbs a.i./A. Sugarbeets (*Beta vulgaris* L.), pigweed (*Amaranthus retroflexus* L.), lambsquarters (*Chenopodium album* L.), and barnyardgrass (*Echinochloa crusgalli* L. Beauv.) were planted on June 24, 1968 with International 185 planters.

Postemergence treatments were applied on July 23, 1968. Air temperature was 71 F. Postemergence treatments included were phenmedipham at 1 and 2 lbs a.i./A and Pyramin Plus at 9 and 12 lbs product/A. Stages of growth of the various plant species differed because of the different rates of cycloate when the postemergence treatments were made. These differences are listed in Table 1.

Table 1. Summary table of list of average number of plant species true leaves* at time of post-emergence herbicide applications. 1968 study at East Farm.

Treatment	lbs a.i. /A	Sugarbeets	Pigweed	Lambsquarters	Barnyardgrass
Untreated	0	2-3	4	4-7	3-5
Cycloate	.25	2-3	3-5	5	3-4
Cycloate	.50	2-3	0-2	0-1	2
Cycloate	1	2-3	0-2	0-1	2
Cycloate	2	2-3	0-2	0-1	2
Cycloate	4	2-3	0-1	0-1	2

*0 = cotyledon leaves only.

Visual evaluation of percent sugarbeet injury and weed control were taken on August 24, 1968.

From the visual evaluations, synergistic, additive, or antagonistic effects of the combinations were determined using Colby's (1967) method of calculating the "expected" response. Thus, if A is the growth as a percent of control with cycloate at p lbs/A, B is the growth as percent of control with phenmedipham at q lbs/A, and E is the expected growth as percent of control with cycloate plus phenmedipham at p plus q lbs/A, then

$$E = \frac{AB}{100}$$

Synergism is indicated when the observed growth as percent of control is less than expected, additivity when observed growth is approximately equal to expected, and antagonism when the observed growth is greater than expected.

Results

Results are given in summary Table 2 and Appendix Tables 1, 2, and 3. Synergistic effects were achieved with most of the cycloate-phenmedipham and cycloate-Pyramin Plus combinations on all weed species. Differences in the stage of growth of the weed species at the time of phenmedipham application did not seem to have an effect on the results.

Results of visual evaluations are given in Appendix Table 1. There was no visual injury with any of the herbicidal treatments. In general, the herbicide combinations controlled the weed species much better than the herbicides alone at comparable rates.

Table 2 is a summary of the calculated responses with a plus sign indicating synergism and a minus sign indicating antagonism. The response of pigweed was greater than expected with nearly all treatments. The same results occurred in lambsquarters. All of the combinations gave equal or better results than expected on barnyardgrass. Some of the results of the combinations were sufficiently greater than expected so that they can undoubtedly be considered synergistic.

Table 2. Summary of cycloate-phenmedipham and cycloate-Pyramin Plus effects on weeds. 1968 study at East Farm.

Treatment	Rate lbs/A	Pigweed			Lambsquarters			Barnyardgrass		
		Observed	Expected[a]	Difference[b]	Observed	Expected[a]	Difference[b]	Observed	Expected[a]	Difference[b]
		(% of check)			(% of check)			(% of check)		
cycloate + phenmedipham	.25 + 1	86	(86)	+ 0	35	(48)	+13	60	(62)	+ 2
cycloate + phenmedipham	.25 + 2	83	(84)	+ 1	5	(42)	+37	47	(60)	+13
cycloate + phenmedipham	.50 + 1	80	(81)	+ 1	26	(40)	+14	47	(56)	+ 9
cycloate + phenmedipham	.50 + 2	76	(79)	+ 3	12	(35)	+23	32	(53)	+ 3
cycloate + phenmedipham	1 + 1	75	(77)	+ 2	36	(37)	+ 1	37	(40)	+ 3
cycloate + phenmedipham	1 + 2	63	(76)	+13	7	(31)	+24	30	(39)	+ 9
cycloate + phenmedipham	2 + 1	20	(23)	+ 3	23	(25)	+ 5	30	(32)	+ 2
cycloate + phenmedipham	2 + 2	8	(22)	+14	5	(22)	+17	8	(30)	+22
cycloate + phenmedipham	4 + 1	5	(19)	+14	2	(23)	+21	10	(0)	+10
cycloate + phenmedipham	4 + 2	3	(18)	+15	0	(21)	+21	0	(0)	+ 0
cycloate + Pyramin Plus	.25 + 9	90	(89)	- 1	86	(67)	-19	66	(62)	+ 4
cycloate + Pyramin Plus	.25 + 12	75	(86)	+11	43	(63)	+20	50	(56)	+ 6
cycloate + Pyramin Plus	.50 + 9	70	(83)	+13	33	(56)	+23	37	(56)	+19
cycloate + Pyramin Plus	.50 + 12	68	(81)	+13	28	(52)	+24	23	(51)	+18
cycloate + Pyramin Plus	1 + 9	70	(80)	+10	33	(49)	+16	12	(40)	+28
cycloate + Pyramin Plus	1 + 12	35	(77)	+42	25	(46)	+21	10	(37)	+27
cycloate + Pyramin Plus	2 + 9	26	(42)	+16	33	(35)	+ 2	2	(32)	+30
cycloate + Pyramin Plus	2 + 12	20	(41)	+21	25	(33)	+ 8	0	(29)	+29
cycloate + Pyramin Plus	4 + 9	11	(20)	+ 9	28	(32)	+ 4	0	(0)	+ 0
cycloate + Pyramin Plus	4 + 12	5	(20)	+15	11	(30)	+19	0	(0)	+ 0
Untreated Check	--									

[a]See Materials and Methods section for method of calculating expected values.

[b]Differences equal expected values minus observed values. A plus sign would indicate synergism and a minus, antagonism.

INTERACTIONS OF CYCLOATE AND PHENMEDIPHAM ON FIELD-GROWN SUGARBEETS AND WEEDS - 1969

Methods and Materials

A field experiment based on results of the preliminary experiment (Effects of Postemergence Herbicides in the Field on Sugarbeets and Weed Species Pre-treated with Cycloate - 1968) was established at the Hyslop Agronomy Farm near Corvallis, Oregon in July 1969. The objectives of the experiment were to study interaction effects of cycloate-phenmedipham combinations on weed species and to determine if the combination treatments have similar effects on sugarbeets as on the weed species.

Cycloate at rates of .25, .50, 1, 2, 4, and 6 lbs a.i./A was applied as a preplant incorporation treatment on July 16, 1969. A tractor-powered rototiller was used to incorporate cycloate to a depth of three inches. Sugarbeets, pigweed, and barnyardgrass were planted with planet Junior planters on the same date. Soil temperature at the time of herbicide incorporation and planting was 67 F. Mustard (Brassica compestris L.) was planted on July 21, 1969.

Phenmedipham was applied postemergence at rates of 2 and 6 lbs a.i./A. The phenmedipham was applied when the sugarbeets were in the two true-leaf stage of growth (Stage I), in the four-leaf stage of growth (Stage II), or in the seven-leaf stage of growth (Stage

III). Air temperature at the time of these applications was between 68-75 F. The stage of growth of pigweed varied according to the rate of cycloate as described in Table 3.

Table 3. Summary table of the stage of growth in cycloate treatments at different phenmedipham applications - 1969 study at Hyslop.

Treatment	Rate lbs a.i./A	Stage I No. of leaves	Stage II No. of leaves	Stage III Inches in height
untreated	0	4	13	16
cycloate	.25	4	13	14
cycloate	.50	4	13	14
cycloate	1	4	12	10
cycloate	2	4	8	10
cycloate	4	2	6	4
cycloate	6	2	0	2

Barnyardgrass and mustard also varied in growth with the different cycloate treatments. There was no barnyardgrass at any of the three application dates in the cycloate treatments above 2 lbs a.i./A. The barnyardgrass was also somewhat retarded in the lower rates. Mustard had not germinated at the time of Stage I application and was stunted by cycloate above 2 lbs a.i./A at the time of Stage II and III applications.

All preplant incorporated and postemergence treatments were applied as a broadcast spray. Spray application was made in water at a volume of 30 gal/A. Application was made with a bicycle-wheel plot sprayer.

The plot design was a split-split plot with time of phenmedipham applications as the main plots, phenmedipham rates as first sub-plots, and cycloate rates as second sub-plots.

Fresh weights (above ground foliage - 3 feet of one row) of pigweed and barnyardgrass were taken on August 7, 1969 just prior to the first application (Stage I) of phenmedipham. The samples were taken to determine more conclusively the effect of cycloate on plant growth (Table 4).

Table 4. Summary table of the average weight of pigweed and barnyardgrass samples just prior to the first phenmedipham application (Stage II) - 1969 study at Hyslop.

Treatment	Rate lbs a.i./A	Fresh wts. of foliage (grams)	
		Pigweed	Barnyardgrass
untreated	0	79.6	91.0
cycloate	.25	69.7	70.2
cycloate	.50	60.8	60.3
cycloate	1	48.8	50.2
cycloate	2	10.4	0.6
cycloate	4	6.5	0.1
cycloate	6	0.1	0.1

Visual evaluations of sugarbeet injury and weed control were taken on September 10, 1969. Samples of sugarbeets, pigweed, and barnyardgrass foliage were taken from Stage I and Stage II plots on

September 16, 1969. All above ground plant material was removed from a row three feet in length. Fresh and dry weights were determined.

To determine the synergistic or antagonistic effects of the combination treatments, data from visual evaluations, fresh weights, and dry weights were examined by Colby's (1967) method of calculating the "expected" response.

Results

Results are summarized in Tables 5, 6, and 7 and in Appendix Tables 4 through 23. The response calculations show a strong indication of synergistic effects on the weed species included in the experiment by most of the cycloate-phenmedipham combination treatments. The synergistic effects occurred in both the fresh weight and dry weight results of Stage I and Stage II and in the visual evaluation data of all three stages.

Visual evaluations of pigweed and barnyardgrass indicated that the control with the combination treatments was better in Stage I than Stages II or III. Visual evaluations of mustard indicated that the best control was achieved with .25 plus 2 and .25 plus 6 lbs a.i./A in Stage III and rates above .50 plus 6 lbs a.i./A in Stage II. Visual evaluations of sugarbeet growth indicated some injury at the higher rates in all three stages.

Table 5. Summary table for calculated responses* for Stage I. 1969 study at Hyslop.

Treatment	Rate lbs a.i./A	Responses Calculated from Visual Evaluations			Responses Calculated from Fresh Weights		Responses Calculated from Dry Weights	
		Pigweed	Barnyardgrass	Mustard	Pigweed	Barnyardgrass	Pigweed	Barnyardgrass
cycloate + phenmedipham	.25 + 2	+12	+16	- 2	+ 2	+ 5	-19	-14
cycloate + phenmedipham	.25 + 6	+ 4	+28	+24	+ 6	+21	+ 8	+10
cycloate + phenmedipham	.50 + 2	+17	+15	+11	-10	-31	-24	-23
cycloate + phenmedipham	.50 + 6	+14	+27	+37	+17	+ 3	+ 7	-12
cycloate + phenmedipham	1 + 2	+21	+16	+19	+12	+ 9	- 7	+ 7
cycloate + phenmedipham	1 + 6	+11	+29	+56	+ 7	+17	+ 6	+18
cycloate + phenmedipham	2 + 2	+23	+ 7	+31	+44	+ 3	+25	+ 4
cycloate + phenmedipham	2 + 6	+12	+ 5	+52	+28	+ 2	+25	+ 2
cycloate + phenmedipham	4 + 2	+ 9	+ 1	+67	+33	+17	+18	+ 3
cycloate + phenmedipham	4 + 6	+ 5	+ 1	+54	+19	+ 9	+15	+ 2
cycloate + phenmedipham	6 + 2	+ 2	+ 1	+70	+ 4	0	+ 2	0
cycloate + phenmedipham	6 + 6	+ 2	+ 1	+51	+ 2	0	+ 2	0

*The response is a difference between observed and expected values. A plus sign would indicate synergism and a minus, antagonism.

Table 6. Summary tables for calculated responses* for Stage II. 1969 study at Hyslop.

Treatment	Rate lbs a.i. /A	Response Calculated from Visual Evaluations			Responses Calculated from Fresh Weights		Responses Calculated from Dry Weights	
		Pigweed	Barnyardgrass	Mustard	Pigweed	Barnyardgrass	Pigweed	Barnyardgrass
cycloate + phenmedipham	.25 + 2	0	- 6	+20	-36	+20	-48	-10
cycloate + phenmedipham	.25 + 6	0	- 7	+26	-20	+92	-14	+54
cycloate + phenmedipham	.50 + 2	+ 6	- 2	+35	-19	+20	-16	+10
cycloate + phenmedipham	.50 + 6	+ 5	- 6	+33	+13	+118	+ 7	+16
cycloate + phenmedipham	1 + 2	+ 8	+13	+44	+27	- 2	+ 7	-13
cycloate + phenmedipham	1 + 6	+11	+16	+33	+28	+41	+10	+18
cycloate + phenmedipham	2 + 2	+ 7	+10	+50	+ 9	+13	+ 6	+ 7
cycloate + phenmedipham	2 + 6	+ 7	+11	+31	+ 4	+21	+ 7	+11
cycloate + phenmedipham	4 + 2	+ 2	+ 5	+47	+13	+ 3	+12	+ 1
cycloate + phenmedipham	4 + 6	+ 2	+ 4	+28	+11	+ 5	+11	+ 1
cycloate + phenmedipham	6 + 2	+ 2	+ 2	+31	+ 5	0	+ 1	0
cycloate + phenmedipham	6 + 6	+ 1	+ 1	+18	+ 4	0	+ 1	0

*The response is a difference between observed and expected values. A plus sign would indicate synergism and a minus, antagonism.

Table 7. Summary table for calculated responses* calculated from visual evaluations of Stage III - 1969 study at Hyslop.

Treatment	Rate lb a. i. /A	Response			
		Pigweed	Barnyardgrass	Mustard	Groundsel
cycloate + phenmedipham	.25 + 2	+14	+ 4	+47	+60
cycloate + phenmedipham	.25 + 6	- 7	+ 4	+83	+60
cycloate + phenmedipham	.50 + 2	-16	+ 1	+42	+60
cycloate + phenmedipham	.50 + 6	- 2	0	+92	+60
cycloate + phenmedipham	1 + 2	-14	+ 9	+77	+60
cycloate + phenmedipham	1 + 6	0	+ 8	+80	+63
cycloate + phenmedipham	2 + 2	- 2	+15	+60	+34
cycloate + phenmedipham	2 + 6	+ 5	+23	+63	+35
cycloate + phenmedipham	4 + 2	+10	+ 9	+50	+39
cycloate + phenmedipham	4 + 6	+ 8	+ 9	+50	+42
cycloate + phenmedipham	6 + 2	+70	0	+43	+34
cycloate + phenmedipham	6 + 6	+65	0	+43	+36

*The response is a difference between observed and expected values. A plus sign would indicate synergism and a minus, antagonism.

Synergistic effects from the combination treatments are indicated by calculated responses in Tables 5 and 6. Synergistic effects are indicated by visual evaluations of all of the weed species in all three stages. Results from Stage III applications indicate synergistic effects on groundsel by the combinations at all rates. There was some antagonism noted on barnyardgrass in Stage III.

Table 5 indicates that high synergistic responses occurred at most rates in the fresh weights of pigweed and barnyardgrass at rates above 1 plus 6 lbs a.i./A in Stage I. Antagonism occurred in the dry weight of pigweed and barnyardgrass in some of the lower rates in Stage I. The antagonism did not occur to the same extent in the fresh weights of Stage I.

Table 6 results for Stage II show high synergistic responses with most treatments on all weed species with all of the combination rates above 1 plus 6 lbs a.i./A. This occurred in both the fresh and dry weights. Some antagonism occurred with the lower rates.

The fresh and dry weights of sugarbeets did not show a severe reduction with any of the treatments in either Stage I or Stage II.

LABORATORY EXPERIMENTS ON THE EFFECT OF CYCLOATE ON THE DEPOSITION OF WAX ON PLANT SPECIES

Method and Materials

Laboratory experiments were conducted in 1969. The objectives of the experiments were (a) to select a solvent for removal of surface wax from plant leaves, (b) to determine the effect of cycloate on cabbage (*Brassica oleracea capitata* L.) leaves, and (c) to determine if cycloate prevented surface wax deposition on leaves of sugarbeets and two weed species.

Three solvents, chloroform, petroleum ether, and ether anhydrous were compared to determine which one was most suitable for surface leaf wax removal. The dissolving properties of each solvent were tested on common candle wax. Of the three solvents, chloroform was superior. Based on these results, chloroform was selected for use in the following experiments.

Leaves from cabbage which had been treated at Hyslop Agronomy Farm with preplant incorporation treatments of cycloate at rates of .25, .50, 1, 2, or 4 lbs a.i./A were analyzed for effects of cycloate on surface wax content. The cabbage leaves were first washed with distilled water to remove any foreign substances such as soil particles from the leaf surface. Plants having 5-6 true leaves were used in the experiment. Twelve discs were removed from a random sample of three leaves using a No. 6 cork bore. The discs were then immediately placed in 25 ml of chloroform in a 150-ml beaker. The discs were allowed to remain in the chloroform for 60 sec. The extract was then removed and placed in a pre-weighed 300-ml distilling flask. The 150-ml beaker was rinsed with 15 ml of chloroform after the discs had been removed to dissolve any remaining extracted wax. The distilling flask was then placed on a vacuum distiller for five minutes with the lower 1/4 portion of the flask in water at 40 C. After the chloroform had been removed by the vacuum distiller the remaining solid extract was weighed in the pre-weighed flasks on a microbalance. Because of the texture and smell the weighed extract was considered to be surface wax removed from cabbage leaf.

Wax was determined for sugarbeets, pigweed, and mustard using the same technique as previously discussed except that 3.4 grams of leaf material was used instead of discs. All three of the plant species had been treated with .25, 1, or 4 lbs a.i./A of cycloate applied as a preplant incorporation treatment (Hyslop Agronomy Farm - 1969). All of the plant species at the time of analyses were at the three-leaf stage of growth.

Results

Results of the laboratory experiments are given in Tables 8, 9, 10, and 11 and Appendix Tables 24, 25, 26, and 27. An analysis of

Table 8. Summary of effects of cycloate on surface wax content of cabbage leaves.

Treatment	Rate lbs a.i./A	mg of wax
untreated check	0	.19
cycloate	.25	.19
cycloate	.50	.19
cycloate	1	.17
cycloate	2	.15
cycloate	4	.14

L.S.D. .01 = .015

Table 9. Summary of cycloate effects on surface wax content of sugarbeet leaves.

Treatment	Rate lbs a.i./A	mg of wax
untreated	0	.01
cycloate	.25	.01
cycloate	1	.03
cycloate	4	.02
cycloate	6	.04

Table 10. Summary of cycloate effects on surface wax content of pigweed leaves.

Treatment	Rate lbs a.i./A	mg of wax
untreated	0	.03
cycloate	.25	.01
cycloate	1	.03
cycloate	4	.02

Table 11. Summary of cycloate effects on surface wax content of mustard leaves.

Treatment	Rate lbs a.i./A	mg of wax
untreated	0	.050
cycloate	.25	.050
cycloate	1	.049
cycloate	4	.047

variance is included in Appendix Tables 24 through 27.

Cycloate treatments caused a distinct reduction of surface wax on cabbage leaves. This reduction in amount of surface wax was greater as the rate of cycloate increased. In the analysis of variance the F value for treatments was significant at the 1% level of probability. Use of the L.S.D. at the 1% level shows a significant difference between treatments of 1/2 and 1, 1 and 2, and 2 and 4 lbs a.i./A of cycloate.

Cycloate had no measurable effect on surface wax of sugarbeet, pigweed, and mustard leaves; however, the quantity of wax on sugarbeets, mustard, and pigweed leaves was much less than for cabbage.

ELECTRON MICROSCOPE STUDIES OF SUGARBEET, PIGWEED, AND BARNYARDGRASS LEAF SURFACES

Methods and Materials

Leaf samples were taken from the field for electron microscope studies. The objective of the studies was to determine if cycloate effects on leaf surface morphology of three plant species could be detected visually.

Leaf samples of sugarbeets, pigweed, and barnyardgrass in the two-true-leaf stage of growth were taken. The three plant species had been treated in the field with cycloate as a preplant incorporated treatment. Rates of cycloate used are as follows: sugarbeets - 0, .25, 1, 2, 4, and 6 lbs a.i./A; pigweed - 0, .25, 1, 2, and 4 lbs a.i./A, and barnyardgrass - 0, .50, 1, and 4 lbs a.i./A.

Within 48 hours of sampling, 4 x 4 millimeter sections of the samples were plated with a gold layer 200 angstroms thick using a vacuum evaporator technique. The replicas were then placed in a scanning electron microscope operating at 45 kilovolts. The replicas were scanned at a 45^{o} beam angle. Micrographs at powers of 300X, 1000X, 3000X, and 10,000X were taken. Positive/negative film in a microscope-mounted Polaroid land camera was used to take the micrographs.

Results

Results are given in Figures 2 through 25. Micrographs of barnyardgrass at 10,000X revealed an apparent reduction of wax rodlets caused by cycloate. The results indicate that cycloate may have an effect on the amount of wax deposition which can be shown in the reduction in number of rodlets.

Micrographs at 10,000X indicate that cycloate also may be having an effect on wax formation as seen in a "cracking" effect on the surface of the pigweed and sugarbeet leaves. In Figures 5 through 14 this cracking effect is shown by small dark lines. Mueller *et al.* (1954) have shown that removal of wax with a solvent from broadleaf plant leaves will leave small cracks on the leaf surface. This "cracking" effect was noted in the micrographs of both pigweed and sugarbeet leaves treated with higher rates of cycloate. No effect of this nature was visible on the untreated leaves of either plant species.

Micrographs of pigweed and sugarbeets also show a difference in stomata opening. Pigweed had more stomata closed in the cycloate-treated plants. There was no effect on stomata in the untreated pigweed. There was no noticeable difference in the stomata of treated and untreated sugarbeet leaves. The stomata were open in all leaves of the cycloate-treated sugarbeets as well as in the untreated plants.

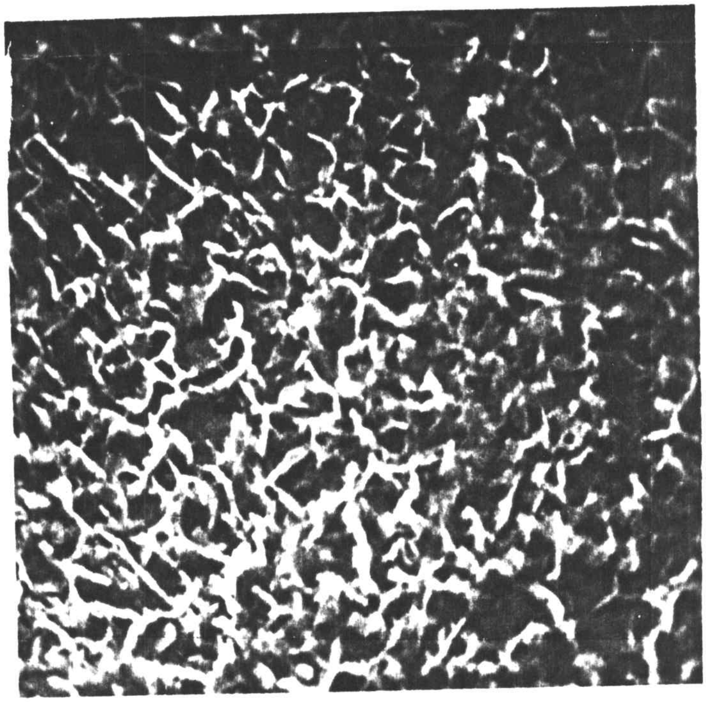


Figure 2. Barnyardgrass leaf surface showing rodlets-untreated. (10,000X).

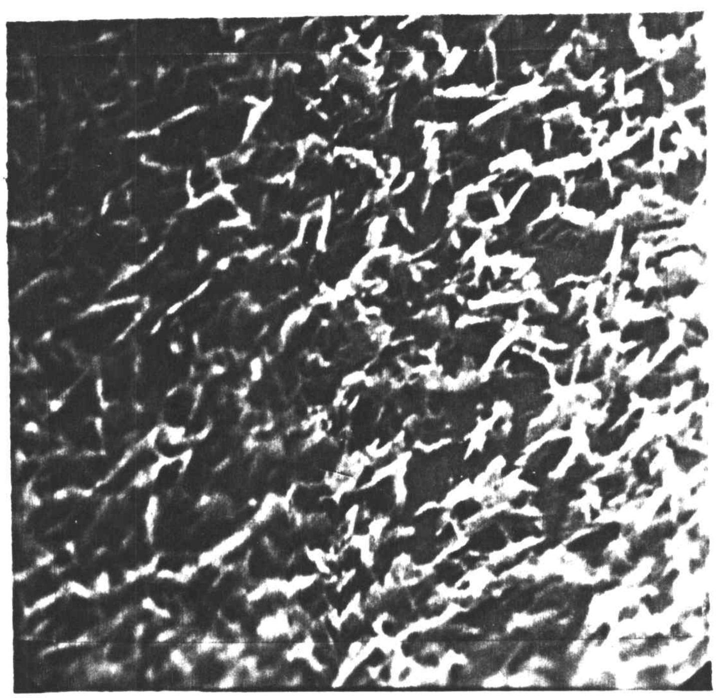


Figure 3. Barnyardgrass leaf surface showing effect of .25 lb a.i./A cycloate on rodlets. (10,000X).

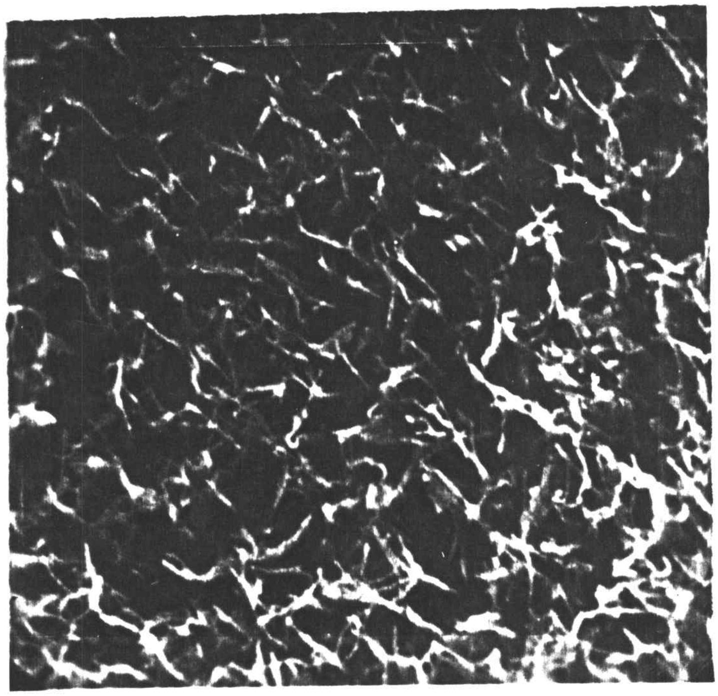


Figure 4. Barnyardgrass leaf surface showing effect of 1 lb a.i./A cycloate on number of rodlets. (10,000X).

Figure 5. Pigweed leaf surface-untreated. (10,000X).

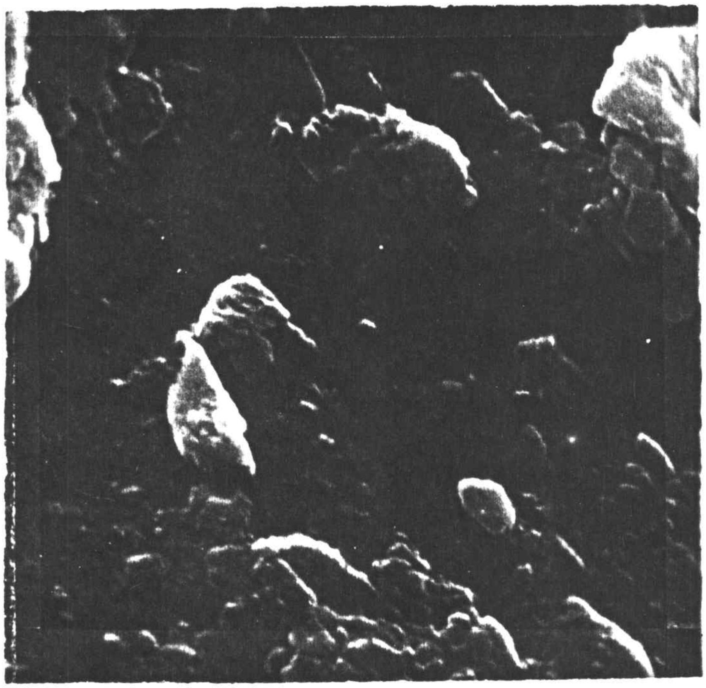


Figure 6. Pigweed leaf surface showing "cracking" effect of .25 lb a.i./A cycloate. (10,000X).

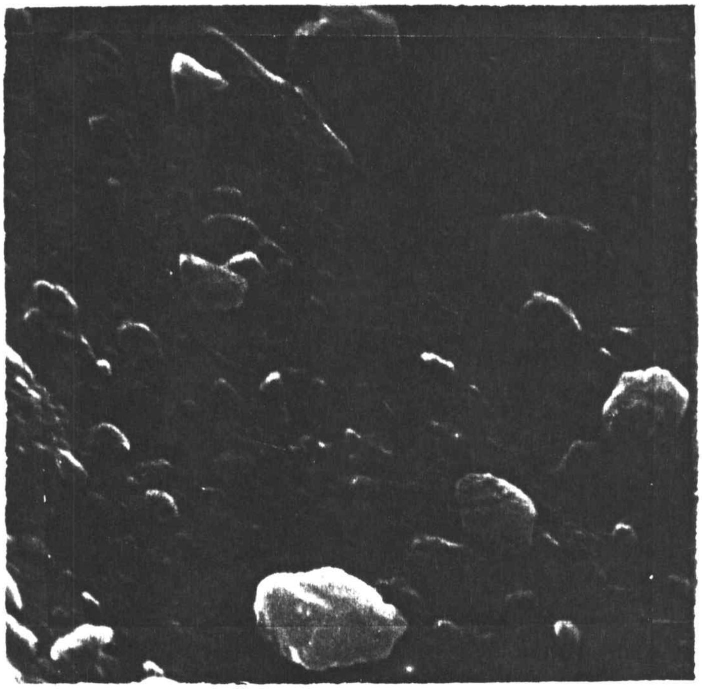


Figure 7. Pigweed leaf surface showing "cracking" effect of 1 lb a.i./A cycloate. (10,000X).

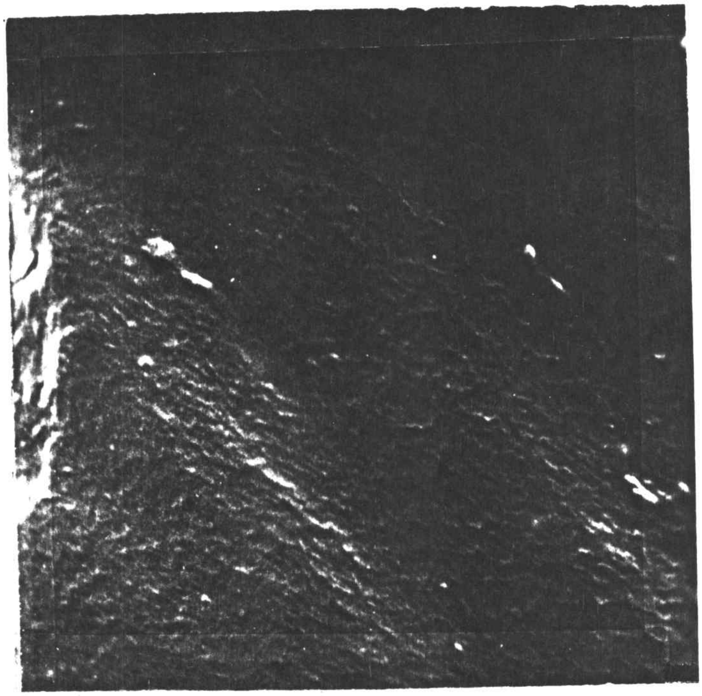


Figure 8. Pigweed leaf surface showing "cracking" effect of 2 lb a.i./A cycloate. (10,000X).

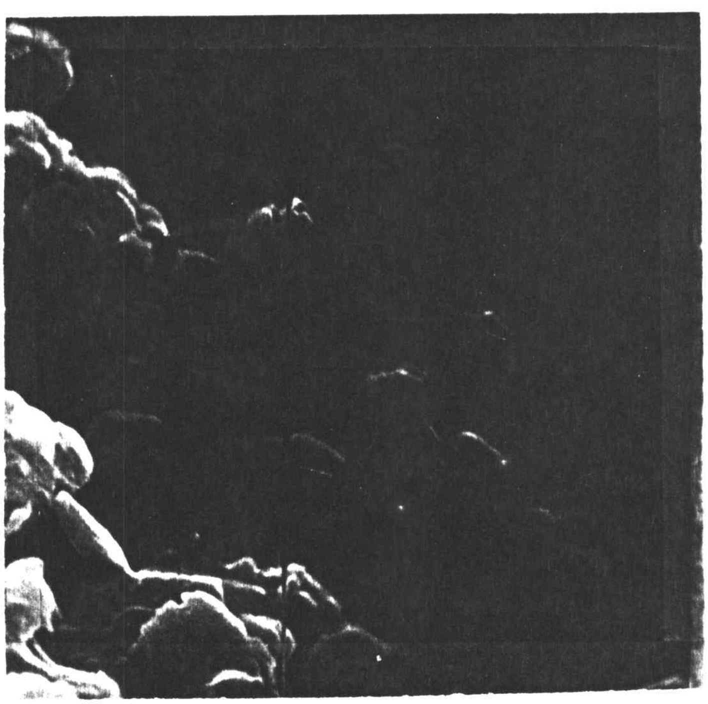


Figure 9. Pigweed leaf surface showing "cracking" effect of 4 lb a.i./A cycloate. (10,000X).

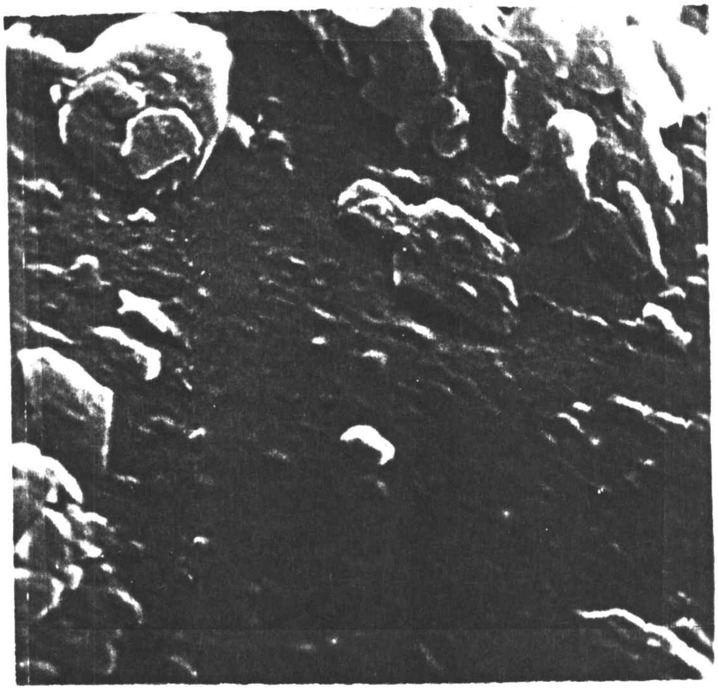


Figure 10. Sugarbeet leaf surface-untreated. (10,000X).

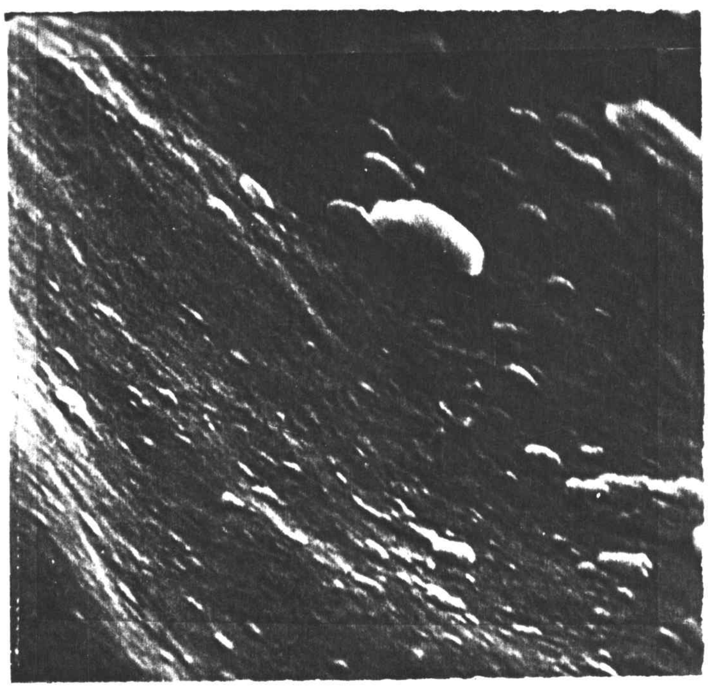


Figure 11. Sugarbeet leaf surface showing "cracking" effect of .25 lb a.i./A cycloate. (10,000X).

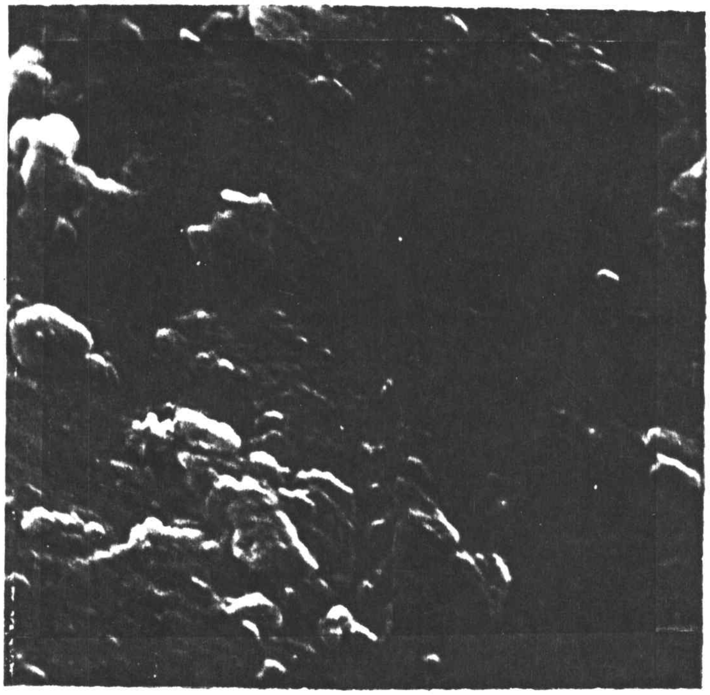


Figure 12. Sugarbeet leaf surface showing "cracking" effect of 1 lb a.i./A cycloate. (10,000X).

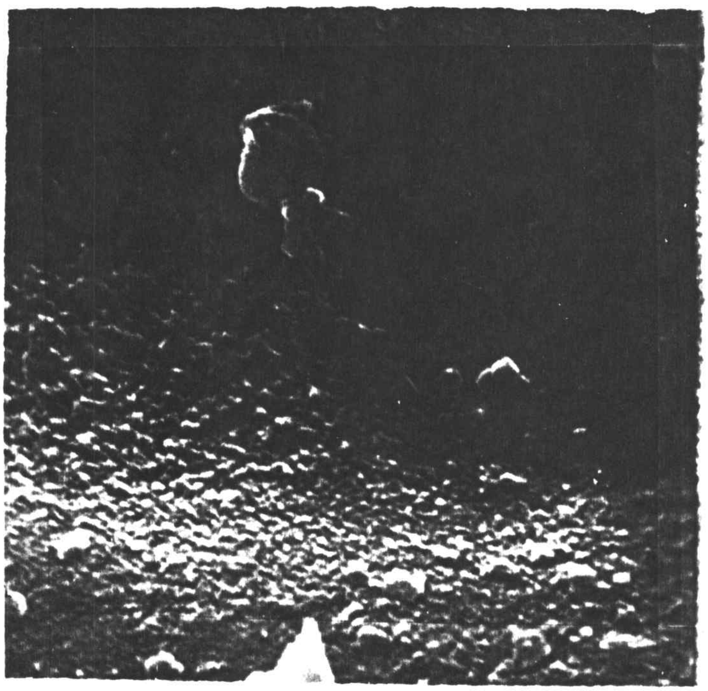


Figure 13. Sugarbeet leaf surface showing "cracking" effect of 2 lb a.i./A cycloate. (10,000X).

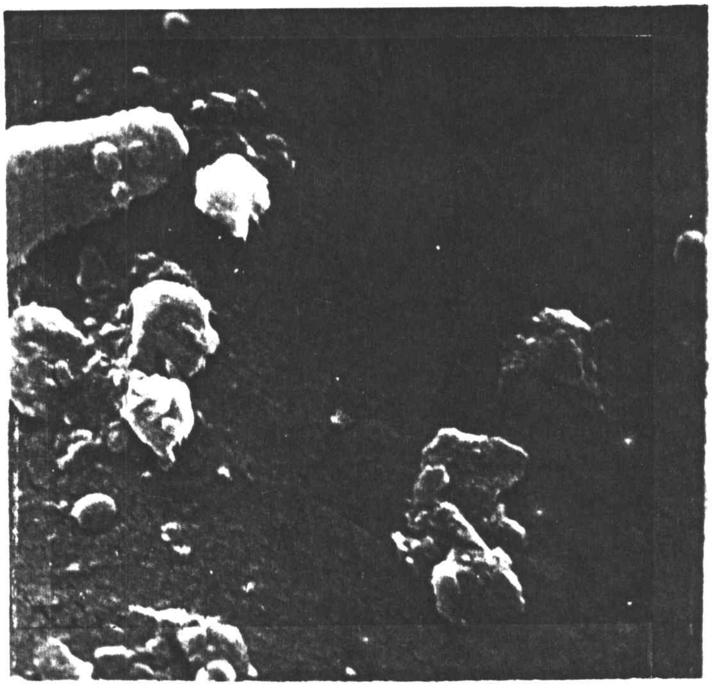


Figure 14. Sugarbeet leaf surface showing "cracking" effect of 4 lb a.i./A cycloate. (10,000X).

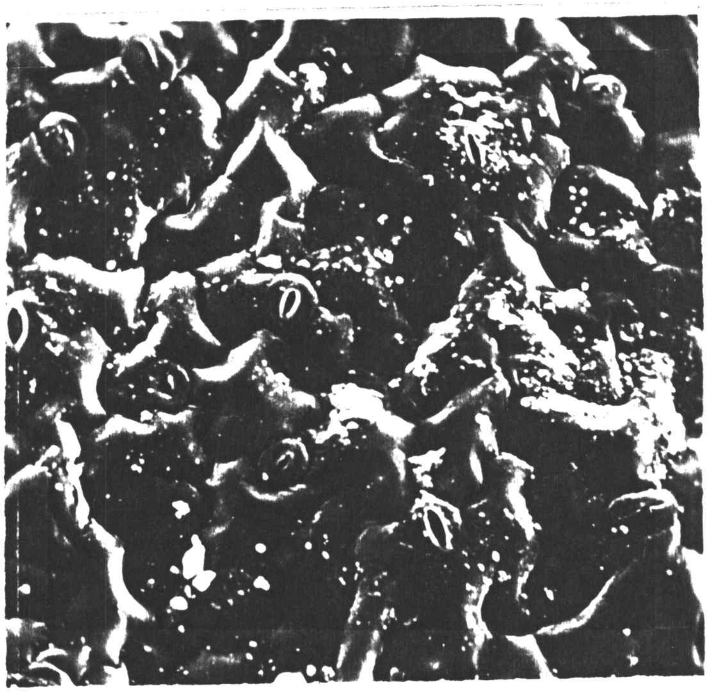


Figure 15. Pigweed leaf surface showing open stomata-untreated. (300X).

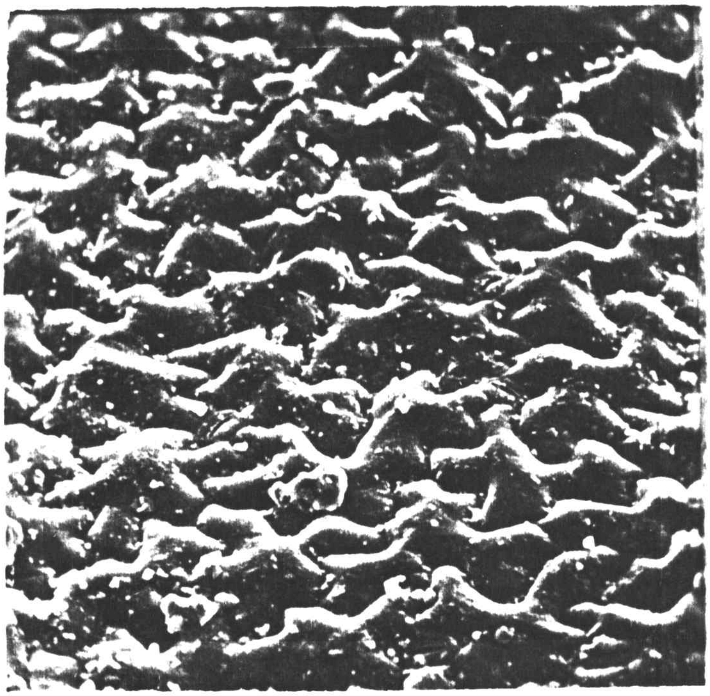


Figure 16. Pigweed leaf surface showing stomata beginning to close with .25 lb a.i./A cycloate. (300X).

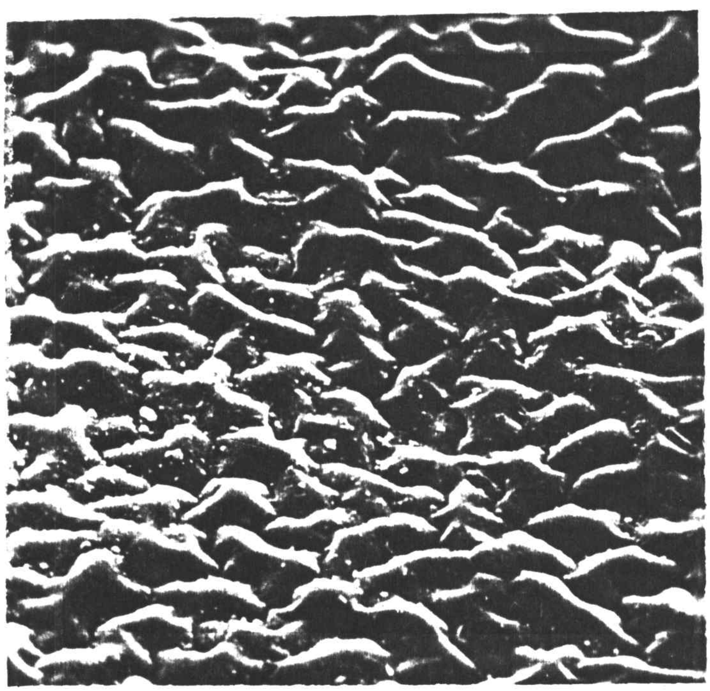


Figure 17. Pigweed leaf surface showing stomata closed with 1 lb a.i./A cycloate. (300X).

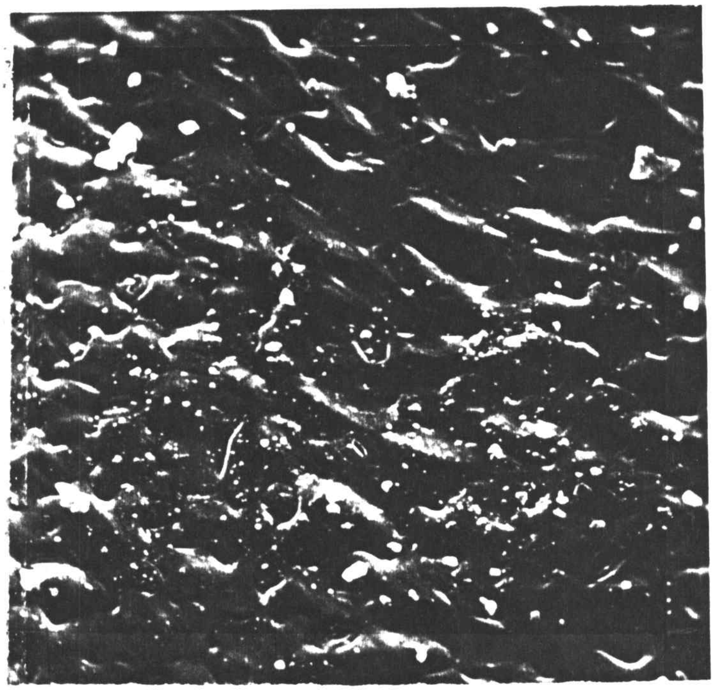


Figure 18. Pigweed leaf surface showing stomata closed with 2 lb a.i./A cycloate. (300X).

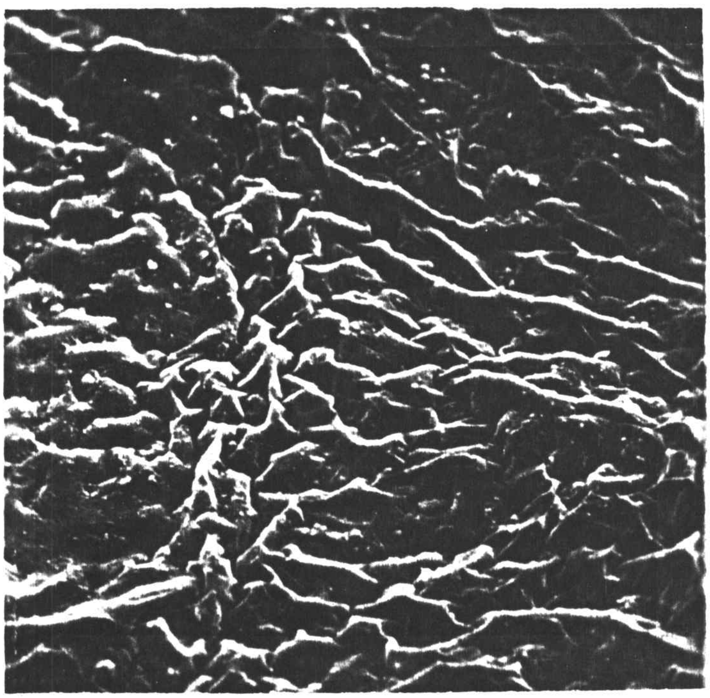


Figure 19. Pigweed leaf surface showing stomata closed with 2 lb a.i./A cycloate. (300X).

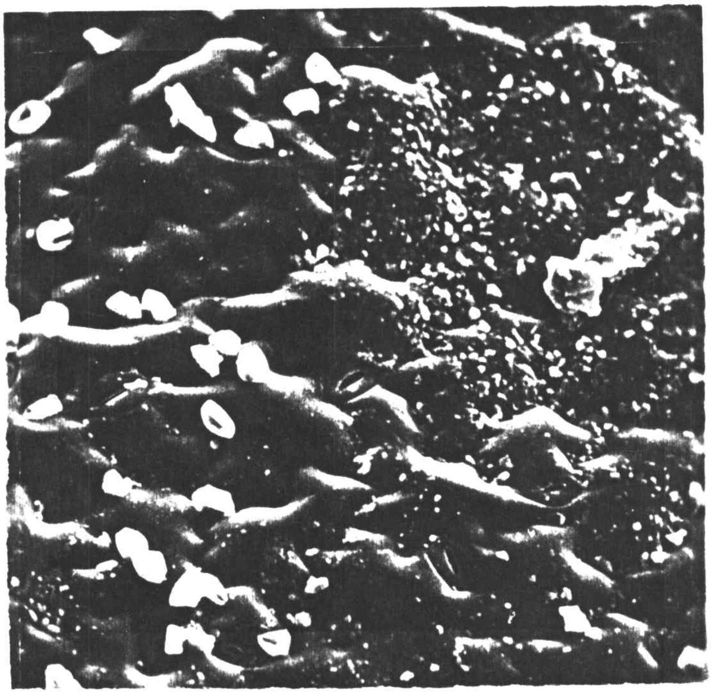


Figure 20. Sugarbeet leaf surface with open stomata. (300X).

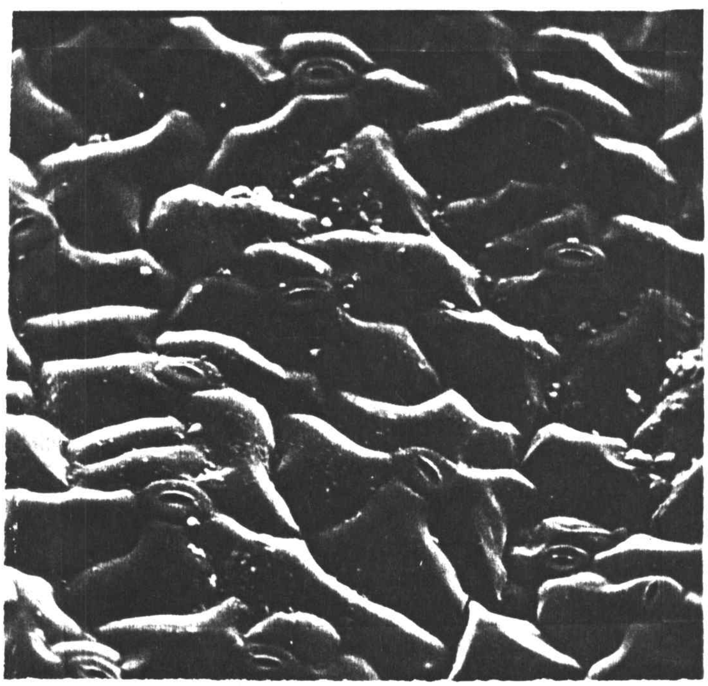


Figure 21. Sugarbeet leaf surface showing open stomata with .25 lb a.i./A cycloate. (300X).

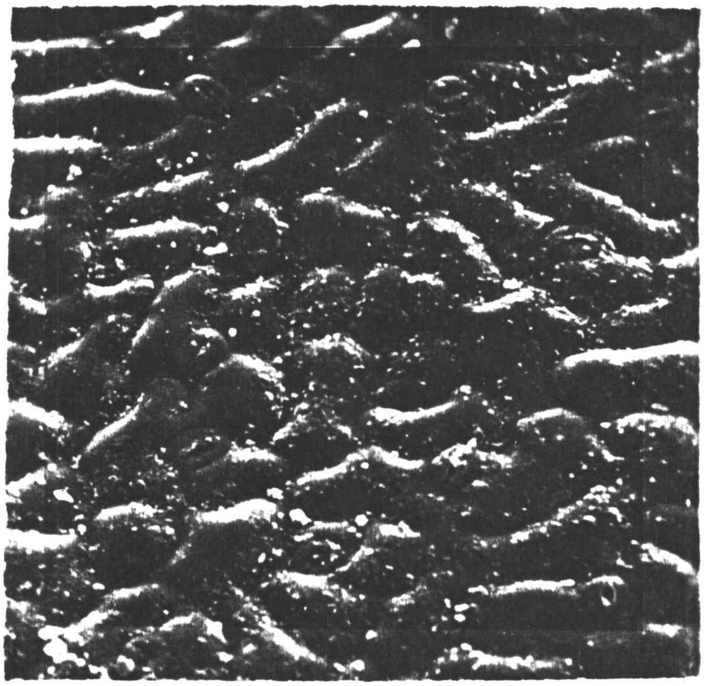


Figure 22. Sugarbeet leaf surface showing open stomata with 1 lb a.i./A cycloate. (300X).

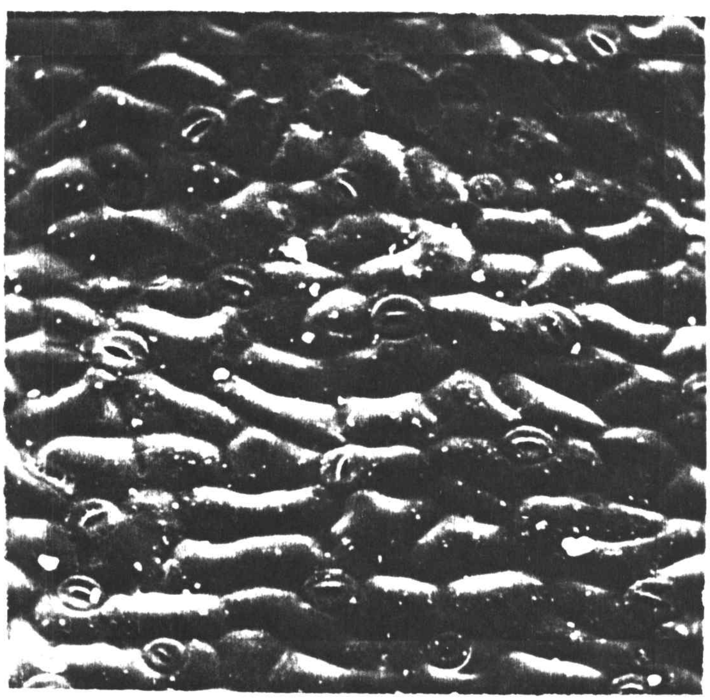


Figure 23. Sugarbeet leaf surface showing open stomata with 2 lb a.i./A cycloate. (300X).

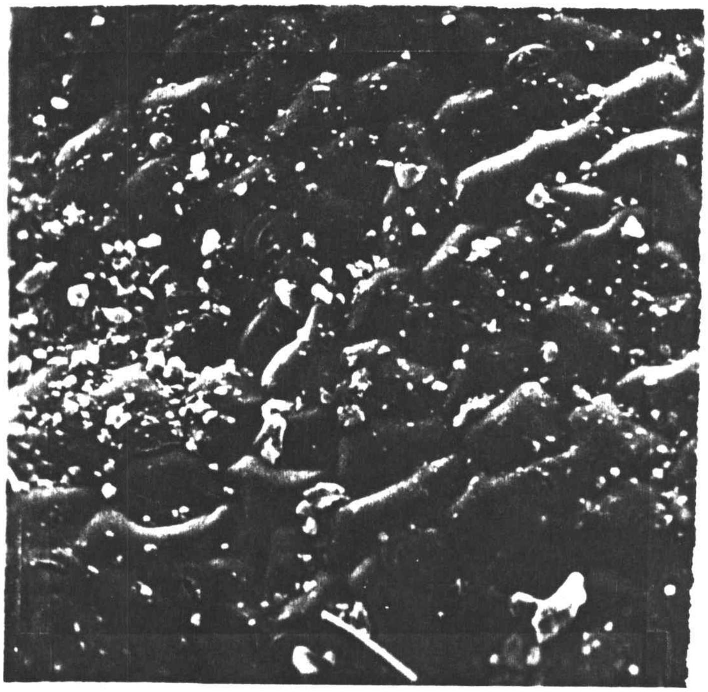


Figure 24. Sugarbeet leaf surface showing open stomata with 4 lb a.i./A cycloate. (300X).

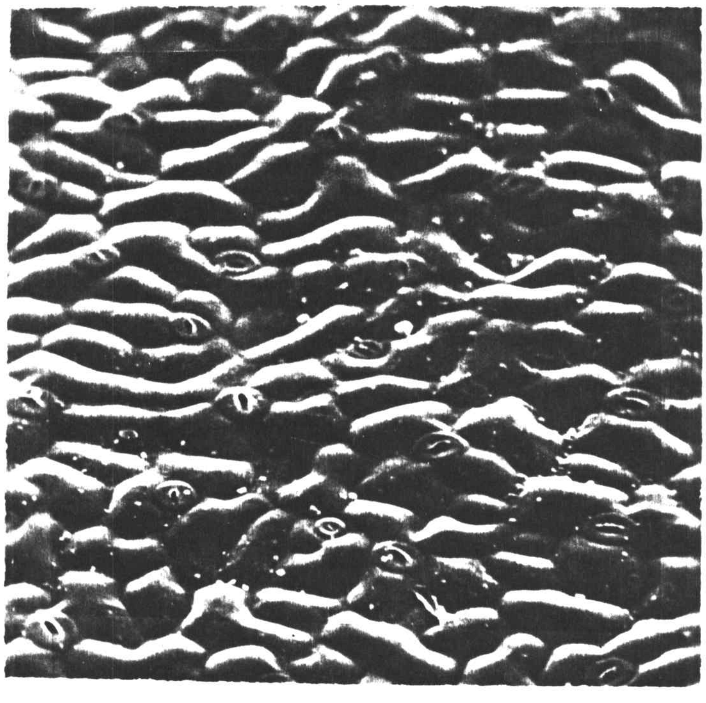


Figure 25. Sugarbeet leaf surface showing open stomata with 6 lb a.i./A cycloate. (300X).

SUMMARY AND DISCUSSION

Field and laboratory experiments were conducted to quantitatively study the nature of interactions between cycloate and post-emergence herbicides on sugarbeets and several weed species. Chemical analysis and electron microscope studies of cycloate effects on cuticular wax formation were carried out in an attempt to determine reasons for these interactions.

In field experiments sugarbeets and several weed species were treated with cycloate and various postemergence herbicides. Interactions of the herbicides in combination were analyzed for synergism by using Colby's (1967) method of calculating the expected responses. For the laboratory experiments, leaf samples of sugarbeets, cabbage, and several weed species treated with various rates of cycloate were taken from the field to measure leaf-surface wax by chloroform extraction. Scanning electron micrographs were made of sugarbeets and two weed species within 48 hours of cutting to determine the effect of cycloate on leaf surface wax.

In the 1968 field study, synergistic effects, as calculated from visual evaluations, were achieved with most of the cycloate-phenmedipham and cycloate-Pyramin Plus combinations on pigweed, lambsquarters, and barnyardgrass. There was no visual sugarbeet injury from any of the combinations. The herbicide combinations controlled all of the weed species much better than each herbicide alone at comparable rates.

In the 1969 field study, calculations from visual evaluations and fresh and dry weights showed synergistic effects on pigweed, mustard, groundsel, and barnyardgrass with most of the cycloate-phenmedipham combinations. The fresh and dry weights of sugarbeets did not show an undesirable reduction with any of the treatments. As in the first field experiment, there was an increase in control of the weed species with the cycloate-phenmedipham combinations over comparable rates of these herbicides alone.

In the wax extraction experiment, cycloate caused a reduction of surface wax on cabbage leaves. This reduction was significant at the 1% level of probability. Cycloate had no significant effect on wax of sugarbeets, pigweed, and mustard leaves. Perhaps the method of analysis used was not sensitive enough to measure a response. The amount of wax on these three species was much less than on cabbage.

Micrographs of sugarbeets, pigweed, and barnyardgrass showed some morphological effects on the leaf surface from the cycloate treatments. Cycloate produced a "cracking" effect on sugarbeets and pigweed leaf surfaces which is indicative of surface wax loss or reduction as shown by Mueller *et al*. (1954) who used solvents to remove surface wax from plant leaves. Stomata of pigweed treated with cycloate remained closed with the stomata of the untreated pigweed and both the untreated and cycloate-treated sugarbeet leaves remained open. Cycloate caused what appeared to be a reduction in the number of wax rodlets on the barnyardgrass leaves.

The synergistic effects on weeds with cycloate-postemergence herbicide combinations may result from an effect of cycloate on surface cuticular leaf wax. Although the reduction of surface wax of pigweed and mustard was not statistically significant, the significant reduction of cabbage wax possibly may be used as a theoretical comparison to predict that the same would be true of pigweed and mustard if a more sensitive method of wax measurement was used. The method would have to be more sensitive than the chloroform technique used to be more conclusive in showing cycloate effect on pigweed and mustard leaves. The visual reduction effects on barnyardgrass rodlets as shown in the micrographs is further evidence that cycloate has an effect on the deposition of wax on plant species other than cabbage.

An indication of other factors which may be playing a role in cycloate-postemergence herbicide synergism is the effect on stomata by cycloate. Since results show that cycloate may be closing the stomata in pigweed leaves, this possible physiological abnormality may be related directly or indirectly to a greater vulnerability to postemergence herbicides. This synergistic achievement may be through a metabolic disturbance produced in the plant by cycloate. Stunting of weeds and closing of stomata in pigweed caused by cycloate indicate that treated and untreated plants are physiologically different. These physiological effects of cycloate may lead to greater sensitivity to postemergence herbicides through mechanisms not yet understood. Possibly a cycloate-treated weed is less capable of degrading phenmedipham, thus increasing its phytotoxicity. Swanson and Swanson (1968) found that simultaneous treatment with certain carbamate insecticides inhibited degradation of monuron in cotton (Gossypium hirsutum L.) leaf discs. Conceivably, similar effects could result from a combination of cycloate and other herbicides.

From a practical standpoint, the synergistic effects of cycloate plus certain postemergence herbicides due to apparent reductions in surface wax deposition and stomatal closure has great value in relation to growing weed-free sugarbeets. Cycloate is one of the principal herbicides used in sugarbeets. With the increase in weed sensitivity to postemergence herbicides due to cycloate, weeds that are not satisfactorily controlled by cycloate can be more effectively controlled with a postemergence herbicide. Also, the total weed control spectrum can be increased.

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APPENDIX

Appendix Table 1. Visual evaluations of percent sugarbeet injury and weed control of cycloate phenmedipham and cycloate-Pyramin Plus treatments. 1968 study at East Farm.

Treatment	Rate lbs/A	Sugarbeets % injury				Pigweed % control				Lambsquarters % control				Barnyardgrass % control			
		Rep I	Rep II	Rep III	Avg	Rep I	Rep II	Rep III	Avg	Rep I	Rep II	Rep III	Avg	Rep I	Rep II	Rep III	Avg
cycloate	.25	0	0	0	0	0	10	0	3	0	10	0	3	10	25	20	22
cycloate	.50	0	0	0	0	10	10	10	10	10	30	20	20	40	20	30	30
cycloate	1	0	0	0	0	10	20	10	13	40	30	20	30	70	30	50	50
cycloate	2	0	0	0	0	75	80	70	75	60	40	50	50	80	40	60	60
cycloate	4	0	0	0	0	75	80	80	78	50	60	50	53	100	100	100	100
phenmedipham	1	0	0	0	0	10	10	10	10	60	50	40	50	20	20	20	20
phenmedipham	2	0	0	0	0	10	10	15	12	70	40	60	56	30	20	20	23
Pyramin Plus	9	0	0	0	0	10	0	10	7	50	10	30	30	20	20	20	20
Pyramin Plus	12	0	0	0	0	10	10	10	10	50	40	10	33	30	20	30	27
cycloate + phenmedipham	.25 + 1	0	0	0	0	20	10	10	13	60	70	65	65	40	60	20	40
cycloate + phenmedipham	.50 + 2	0	0	0	0	20	10	20	17	100	90	95	95	60	50	50	53
cycloate + phenmedipham	.50 + 1	0	0	0	0	20	10	30	20	75	75	70	73	70	40	50	53
cycloate + phenmedipham	.50 + 2	0	0	0	0	40	10	20	23	90	80	90	87	90	70	40	67
cycloate + phenmedipham	1 + 1	0	0	0	0	30	25	20	25	75	50	65	63	70	50	70	60
cycloate + phenmedipham	1 + 2	0	0	0	0	40	30	40	38	95	95	90	93	90	50	70	70
cycloate + phenmedipham	2 + 1	0	0	0	0	80	80	80	80	75	70	85	77	80	60	70	70
cycloate + phenmedipham	2 + 2	0	0	0	0	95	90	90	91	100	90	95	95	100	85	90	92
cycloate + phenmedipham	4 + 1	0	0	0	0	95	95	95	95	100	90	100	98	100	90	80	90
cycloate + phenmedipham	4 + 2	0	0	0	0	100	95	95	97	100	100	100	100	100	100	100	100
cycloate + Pyramin Plus	.25 + 9	0	0	0	0	10	10	10	10	10	20	10	13	30	40	30	33
cycloate + Pyramin Plus	.25 + 12	0	0	0	0	30	20	25	25	40	60	70	57	50	50	50	50
cycloate + Pyramin Plus	.50 + 9	0	0	0	0	30	30	30	30	75	60	65	67	80	50	60	63
cycloate + Pyramin Plus	.50 + 12	0	0	0	0	30	35	30	31	85	70	60	72	85	70	75	77
cycloate + Pyramin Plus	1 + 9	0	0	0	0	30	30	30	30	70	60	70	67	90	85	90	88
cycloate + Pyramin Plus	1 + 12	0	0	0	0	85	60	50	65	90	65	70	75	90	90	90	90
cycloate + Pyramin Plus	2 + 9	0	0	0	0	80	70	70	73	70	60	70	67	100	95	100	98
cycloate + Pyramin Plus	2 + 12	0	0	0	0	80	80	80	80	95	60	70	75	100	100	100	100
cycloate + Pyramin Plus	4 + 9	0	0	0	0	80	95	90	88	70	75	70	72	100	100	100	100
cycloate + Pyramin Plus	4 + 12	0	0	0	0	95	95	95	95	95	80	90	88	100	100	100	100
untreated check	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 2. Visual evaluations calculated responses* for cycloate-phenmedipham treatments - 1968 study at East Farm.

Treatment	Rate lbs a.i./A	Pigweed Response of check			Lambsquarters Response of check			Barnyardgrass Response of check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	96			97			78		
cycloate	.50	90			80			70		
cycloate	1	86			70			50		
cycloate	2	25			50			40		
cycloate	4	21			47			0		
phenmedipham	1	90			50			80		
phenmedipham	2	88			44			77		
cycloate + phenmedipham	.25 + 1	86	(86)	+ 0	35	(48)	+13	60	(48)	+13
cycloate + phenmedipham	.25 + 2	83	(84)	+ 1	5	(42)	+37	47	(42)	+37
cycloate + phenmedipham	.50 + 1	80	(81)	+ 1	26	(40)	+14	47	(40)	+14
cycloate + phenmedipham	.50 + 1	76	(79)	+ 3	12	(35)	+23	32	(35)	+23
cycloate + phenmedipham	1 + 1	75	(77)	+ 2	36	(37)	+ 1	37	(37)	+ 1
cycloate + phenmedipham	1 + 2	63	(76)	+13	7	(31)	+24	30	(31)	+24
cycloate + phenmedipham	2 + 1	20	(23)	+ 3	23	(25)	+ 5	30	(25)	+ 5
cycloate + phenmedipham	2 + 2	8	(22)	+14	5	(22)	+17	8	(22)	+17
cycloate + phenmedipham	4 + 1	5	(19)	+14	2	(23)	+21	10	(23)	+21
cycloate + phenmedipham	4 + 2	3	(18)	+15	0	(21)	+21	0	(21)	+21
untreated check	--									

*Expected responses for combinations are shown in parenthesis following each observed response. The differences between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 3. Visual evaluations calculated responses* for cycloate-Pyramin Plus treatments - 1968 study at East Farm.

Treatment	Rate lbs a. i. /A	Pigweed % of untreated check Obs.	Exp.	Diff.	Lambsquarters % of untreated check Obs.	Exp.	Diff.	Barnyardgrass % of untreated check Obs.	Exp.	Diff.
cycloate	.25	96			96			78		
cycloate	.50	90			80			70		
cycloate	1	86			70			50		
cycloate	2	45			50			40		
cycloate	4	22			46			0		
Pyramin Plus	9	93			70			80		
Pyramin Plus	12	90			66			73		
cycloate + Pyramin Plus	.25 + 9	90	(89)	- 1	86	(67)	-19	66	(62)	- 4
cycloate + Pyramin Plus	.25 + 12	75	(86)	+11	43	(63)	+20	50	(56)	+ 6
cycloate + Pyramin Plus	.50 + 9	70	(83)	+13	33	(56)	+23	37	(56)	+19
cycloate + Pyramin Plus	.50 + 12	68	(81)	+13	28	(52)	+24	23	(51)	+18
cycloate + Pyramin Plus	1 + 9	70	(80)	+10	33	(49)	+16	12	(40)	+28
cycloate + Pyramin Plus	1 + 12	35	(77)	+42	25	(46)	+21	10	(37)	+27
cycloate + Pyramin Plus	2 + 9	26	(42)	+16	33	(35)	+ 2	2	(32)	+30
cycloate + Pyramin Plus	2 + 12	20	(41)	+21	25	(33)	+ 8	0	(29)	+29
cycloate + Pyramin Plus	4 + 9	11	(20)	+ 9	28	(32)	+ 4	0	(0)	+ 0
cycloate + Pyramin Plus	4 + 12	5	(20)	+15	11	(30)	+19	0	(0)	+ 0
untreated check	--									

*Expected response for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 4. Pigweed, barnyardgrass, and mustard response* calculated from visual evaluations (Stage I) - 1969 study at Hyslop.

Treatment	Rate lbs a. i./A	Pigweed Response % of untreated check Obs.	Exp.	Diff.	Barnyardgrass Response % of untreated check Obs.	Exp.	Diff.	Mustard Response % of untreated check Obs.	Exp.	Diff.
cycloate	.25	71			74			98		
cycloate	.50	70			62			94		
cycloate	1	70			64			98		
cycloate	2	39			9			99		
cycloate	4	14			2			89		
cycloate	6	4			1			82		
phenmedipham	2	72			77			97		
phenmedipham	6	33			59			63		
cycloate + phenmedipham	.25 + 2	39	(51)	+12	41	(51)	+16	97	(95)	- 2
cycloate + phenmedipham	.25 + 6	19	(23)	+ 4	16	(44)	+28	38	(62)	+24
cycloate + phenmedipham	.50 + 2	33	(50)	+17	33	(48)	+15	80	(91)	+11
cycloate + phenmedipham	.50 + 6	9	(23)	+14	10	(37)	+27	22	(59)	+37
cycloate + phenmedipham	1 + 2	29	(50)	+21	33	(49)	+16	76	(95)	+19
cycloate + phenmedipham	1 + 6	12	(23)	+11	9	(38)	+29	6	(62)	+56
cycloate + phenmedipham	2 + 2	5	(28)	+23	0	(7)	+ 7	65	(96)	+31
cycloate + phenmedipham	2 + 6	1	(13)	+12	0	(5)	+ 5	10	(62)	+52
cycloate + phenmedipham	4 + 2	1	(10)	+ 9	0	(1)	+ 1	19	(86)	+67
cycloate + phenmedipham	4 + 6	0	(5)	+ 5	0	(1)	+ 1	2	(56)	+54
cycloate + phenmedipham	6 + 2	1	(3)	+ 2	0	(1)	+ 1	10	(80)	+70
cycloate + phenmedipham	6 + 6	0	(2)	+ 2	0	(1)	+ 1	1	(52)	+51
untreated check	--	100	--	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The differences between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 5. Pigweed and barnyardgrass responses* calculated from fresh weights (Stage I) - 1969 study at Hyslop.

Treatment	Rate lb a.i./A	Pigweed Response % of untreated check			Barnyardgrass Response % of untreated check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	83			98		
cycloate	.50	71			49		
cycloate	1	73			55		
cycloate	2	56			4		
cycloate	4	34			20		
cycloate	6	4			0		
phenmedipham	2	86			85		
phenmedipham	6	50			43		
cycloate + phenmedipham	.25 + 2	69	(71)	+ 2	79	(84)	+ 5
cycloate + phenmedipham	.25 + 6	36	(42)	+ 6	21	(42)	+21
cycloate + phenmedipham	.50 + 2	70	(60)	-10	73	(42)	-31
cycloate + phenmedipham	.50 + 6	18	(35)	+17	18	(21)	+ 3
cycloate + phenmedipham	1 + 2	51	(63)	+12	38	(47)	+ 9
cycloate + phenmedipham	1 + 6	30	(37)	+ 7	7	(24)	+17
cycloate + phenmedipham	2 + 2	4	(48)	+44	0	(3)	+ 3
cycloate + phenmedipham	2 + 6	0	(28)	+28	0	(2)	+ 2
cycloate + phenmedipham	4 + 2	0	(33)	+33	0	(17)	+17
cycloate + phenmedipham	4 + 6	0	(19)	+19	0	(9)	+ 9
cycloate + phenmedipham	6 + 2	0	(4)	+ 4	0	(0)	+ 0
cycloate + phenmedipham	6 + 6	0	(2)	+ 2	0	(0)	+ 0
untreated check	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 6. Pigweed and barnyardgrass responses* calculated from dry weights (Stage I) - 1969 study at Hyslop.

Treatment	Rate lbs a. i. /A	Pigweed Response % of untreated check Obs.	Exp.	Diff.	Barnyardgrass Response % of untreated check Obs.	Exp.	Diff.
cycloate	.25	94			79		
cycloate	.50	72			55		
cycloate	1	72			58		
cycloate	2	55			5		
cycloate	4	33			4		
cycloate	6	4			0		
phenmedipham	2	54			77		
phenmedipham	6	45			44		
cycloate + phenmedipham	.25 + 2	69	(50)	-19	75	(61)	-14
cycloate + phenmedipham	.25 + 6	34	(42)	+ 8	25	(35)	+10
cycloate + phenmedipham	.50 + 2	63	(39)	-24	65	(42)	-23
cycloate + phenmedipham	.50 + 6	25	(32)	+ 7	36	(24)	-12
cycloate + phenmedipham	1 + 2	46	(39)	- 7	38	(45)	+ 7
cycloate + phenmedipham	1 + 6	26	(32)	+ 6	8	(26)	+18
cycloate + phenmedipham	2 + 2	4	(29)	+25	0	(4)	+ 4
cycloate + phenmedipham	2 + 6	0	(25)	+25	0	(2)	+ 2
cycloate + phenmedipham	4 + 2	0	(18)	+18	0	(3)	+ 3
cycloate + phenmedipham	4 + 6	0	(15)	+15	0	(2)	+ 2
cycloate + phenmedipham	6 + 2	0	(2)	+ 2	0	(0)	+ 0
cycloate + phenmedipham	6 + 6	0	(2)	+ 2	0	(0)	+ 0
untreated check	--						

*Expected responses for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 7. Pigweed, barnyardgrass, and mustard response* calculated from visual evaluations (Stage II) - 1969 study at Hyslop.

Treatment	Rate lbs a. i. /A	Pigweed Response % of untreated check			Barnyardgrass Response % of untreated check			Mustard Response % of untreated check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	47			96			99		
cycloate	.50	57			99			99		
cycloate	1	47			39			98		
cycloate	2	32			17			90		
cycloate	4	9			6			81		
cycloate	6	2			2			53		
phenmedipham	2	79			79			58		
phenmedipham	6	57			70			34		
cycloate + phenmedipham	.25 + 2	37	(37)	+ 0	82	(76)	- 6	37	(57)	+20
cycloate + phenmedipham	.25 + 6	27	(27)	+ 0	74	(67)	- 7	8	(34)	+26
cycloate + phenmedipham	.50 + 2	38	(44)	+ 6	80	(78)	- 2	22	(57)	+35
cycloate + phenmedipham	.50 + 6	27	(32)	+ 5	75	(69)	- 6	1	(34)	+33
cycloate + phenmedipham	1 + 2	29	(37)	+ 8	18	(31)	+13	13	(57)	+44
cycloate + phenmedipham	1 + 6	16	(27)	+11	11	(27)	+16	0	(33)	+33
cycloate + phenmedipham	2 + 2	18	(25)	+ 7	3	(13)	+10	2	(52)	+50
cycloate + phenmedipham	2 + 6	11	(18)	+ 7	1	(12)	+11	0	(31)	+31
cycloate + phenmedipham	4 + 2	5	(7)	+ 2	0	(5)	+ 5	0	(47)	+47
cycloate + phenmedipham	4 + 6	3	(5)	+ 2	0	(4)	+ 4	0	(28)	+28
cycloate + phenmedipham	6 + 2	0	(2)	+ 2	0	(2)	+ 2	0	(31)	+31
cycloate + phenmedipham	6 + 6	0	(1)	+ 1	0	(1)	+ 1	0	(18)	+18
untreated check	--	100	--	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The differences between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 8. Pigweed and barnyardgrass responses* calculated from fresh weights (Stage II) - 1969 study at Hyslop.

Treatment	lbs a. i. /A	Pigweed Response % of untreated check			Barnyardgrass Response % of untreated check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	90			145		
cycloate	.50	86			143		
cycloate	1	129			54		
cycloate	2	68			16		
cycloate	4	24			4		
cycloate	6	5			0		
phenmedipham	2	101			89		
phenmedipham	6	95			129		
cycloate + phenmedipham	.25 + 2	126	(90)	-36	108	(128)	+20
cycloate + phenmedipham	.25 + 6	105	(85)	-20	95	(187)	+92
cycloate + phenmedipham	.50 + 2	106	(87)	-19	107	(127)	+20
cycloate + phenmedipham	.50 + 6	68	(81)	+13	66	(184)	+118
cycloate + phenmedipham	1 + 2	103	(130)	+27	51	(49)	- 2
cycloate + phenmedipham	1 + 6	94	(122)	+28	29	(70)	+41
cycloate + phenmedipham	2 + 2	59	(68)	+ 9	3	(14)	+13
cycloate + phenmedipham	2 + 6	60	(64)	+ 4	0	(21)	+21
cycloate + phenmedipham	4 + 2	9	(24)	+13	0	(3)	+ 3
cycloate + phenmedipham	4 + 6	11	(22)	+11	0	(5)	+ 5
cycloate + phenmedipham	6 + 2	0	(5)	+ 5	0	(0)	+ 0
cycloate + phenmedipham	6 + 6	0	(4)	+ 4	0	(0)	+ 0
untreated check	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 9. Pigweed and barnyardgrass responses* calculated from dry weights (Stage II) - 1969 study at Hyslop.

Treatment	Rate lb a.i./A	Pigweed Response % of untreated check			Barnyardgrass Response % of untreated check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	56			140		
cycloate	.50	78			133		
cycloate	1	102			43		
cycloate	2	56			13		
cycloate	4	18			2		
cycloate	6	7			0		
phenmedipham	2	92			78		
phenmedipham	6	73			87		
cycloate + phenmedipham	.25 + 2	100	(52)	-48	97	(87)	-10
cycloate + phenmedipham	.25 + 6	55	(41)	-14	68	(122)	+54
cycloate + phenmedipham	.50 + 2	88	(72)	-16	94	(104)	+10
cycloate + phenmedipham	.50 + 6	50	(57)	+ 7	100	(116)	+16
cycloate + phenmedipham	1 + 2	87	(94)	+ 7	46	(33)	-13
cycloate + phenmedipham	1 + 6	65	(75)	+10	19	(37)	+18
cycloate + phenmedipham	2 + 2	46	(52)	+ 6	3	(10)	+ 7
cycloate + phenmedipham	2 + 6	34	(41)	+ 7	0	(11)	+11
cycloate + phenmedipham	4 + 2	5	(17)	+12	0	(1)	+ 1
cycloate + phenmedipham	4 + 6	2	(13)	+11	0	(1)	+ 1
cycloate + phenmedipham	6 + 2	0	(1)	+ 1	0	(0)	+ 0
cycloate + phenmedipham	6 + 6	0	(1)	+ 1	0	(0)	+ 0
untreated check	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 10. Pigweed, barnyardgrass, mustard, groundsel response* calculated from visual evaluations (Stage III) - 1969 study at Hyslop.

Treatment	Rate lb a.i./A	Pigweed Response % of untreated check			Barnyardgrass Response % of untreated check			Mustard Response % of untreated check			Groundsel Response % of untreated check		
		Obs.	Exp.	Diff.	Obs.	Exp.	Diff.	Obs.	Exp.	Diff.	Obs.	Exp.	Diff.
cycloate	.25	87			91			90			100		
cycloate	.25	83			92			100			100		
cycloate	1	73			80			85			90		
cycloate	2	55			33			65			53		
cycloate	4	20			9			50			60		
cycloate	6	10			0			43			52		
phenmedipham	2	73			79			10			7		
phenmedipham	6	67			95			10			7		
cycloate + phenmedipham	.25 + 2	78	(64)	-14	92	(96)	+ 4	43	(90)	+47	10	(70)	+60
cycloate + phenmedipham	.25 + 6	65	(58)	- 7	88	(92)	+ 4	7	(90)	+83	10	(70)	+60
cycloate + phenmedipham	.50 + 2	77	(61)	-16	90	(91)	+ 1	58	(100)	+42	10	(70)	+60
cycloate + phenmedipham	.50 + 6	58	(56)	- 2	87	(87)	+ 0	8	(100)	+92	10	(70)	+60
cycloate + phenmedipham	1 + 2	67	(53)	-14	70	(79)	+ 9	8	(85)	+77	3	(63)	+60
cycloate + phenmedipham	1 + 6	50	(50)	+ 0	68	(76)	+ 8	5	(85)	+80	0	(63)	+63
cycloate + phenmedipham	2 + 2	42	(40)	- 2	18	(33)	+15	5	(65)	+60	3	(37)	+34
cycloate + phenmedipham	2 + 6	32	(37)	+ 5	8	(31)	+23	2	(65)	+63	2	(37)	+35
cycloate + phenmedipham	4 + 2	5	(15)	+10	0	(9)	+ 9	0	(50)	+50	3	(42)	+39
cycloate + phenmedipham	4 + 6	5	(13)	+ 8	0	(9)	+ 9	0	(50)	+50	0	(42)	+42
cycloate + phenmedipham	6 + 2	3	(73)	+70	0	(0)	+ 0	0	(43)	+43	2	(36)	+34
cycloate + phenmedipham	6 + 6	2	(67)	+65	0	(0)	+ 0	0	(43)	+43	0	(36)	+36
untreated check	--	100	--	--	100	--	--	100	--	--	100	--	--

*Expected responses for combinations are shown in parenthesis following each observed response. The difference between observed and expected values are also shown. A plus sign would indicate synergism and a minus, antagonism.

Appendix Table 11. Visual evaluations of percent sugarbeet injury (Stage I) - 1969 study at Hyslop.

Treatments	Rate lb a.i./A	Sugarbeets % injury Observations 1	2	3	Total	Avg	Sugarbeets % injury Observations 1	2	3	Total	Avg	Sugarbeets % injury Observations 1	2	3	Total	Avg	TOTAL
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 6	0	0	0	0	0	10	5	0	15	5	5	5	0	10	3	25
cycloate + phenmedipham	1 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	1 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	1 + 6	0	0	0	0	0	5	5	5	15	5	10	0	0	10	3	35
cycloate + phenmedipham	2 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	2 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	2 + 6	10	15	10	35	12	10	10	5	25	8	10	10	0	20	6	80
cycloate + phenmedipham	4 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	4 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	4 + 6	20	15	5	40	13	30	15	10	45	15	30	0	0	30	10	117
cycloate + phenmedipham	6 + 0	10	10	10	30	10	0	0	0	0	0	10	10	0	20	6	50
cycloate + phenmedipham	6 + 2	15	10	10	35	12	10	10	0	20	6	5	10	0	10	5	65
cycloate + phenmedipham	6 + 6	30	25	40	95	32	35	20	20	75	25	30	30	20	80	27	250

Appendix Table 12. Visual evaluations of percent pigweed control (Stage I) - 1969 study at Hyslop.

		Pigweed % control					Pigweed % control					Pigweed % control						
	Rate	Observation					Observation					Observation						TOTAL
Treatments	lbs a. i. /A	I	II	III	Tot.	Avg	I	II	III	Tot.	Avg	I	II	III	Tot.	Avg	TOTAL	AVG
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	10	20	15	45	15	30	40	40	110	37	40	40	20	100	33	255	28
cycloate + phenmedipham	0 + 6	60	70	70	200	67	50	70	70	190	63	70	80	60	210	70	600	67
cycloate + phenmedipham	.25 + 0	20	30	30	80	27	30	40	30	100	33	20	30	30	80	27	260	29
cycloate + phenmedipham	.25 + 2	50	75	70	195	65	40	65	60	165	55	50	65	70	185	62	545	61
cycloate + phenmedipham	.25 + 6	85	95	85	265	88	75	85	75	235	78	70	85	75	230	77	730	81
cycloate + phenmedipham	.50 + 0	20	30	40	90	30	30	40	20	90	30	30	30	30	90	30	270	30
cycloate + phenmedipham	.50 + 2	70	70	50	190	63	60	75	65	200	67	75	80	60	215	72	605	67
cycloate + phenmedipham	.50 + 6	90	95	90	275	92	85	95	80	260	87	95	95	90	280	93	815	91
cycloate + phenmedipham	1 + 0	30	30	40	100	33	10	30	30	70	23	30	40	30	100	33	270	30
cycloate + phenmedipham	1 + 2	60	80	70	210	70	50	85	80	215	72	60	80	70	210	70	635	71
cycloate + phenmedipham	1 + 6	90	90	80	260	87	85	95	95	275	92	85	95	80	260	87	795	88
cycloate + phenmedipham	2 + 0	60	50	70	180	60	50	50	50	150	50	75	70	70	215	72	545	61
cycloate + phenmedipham	2 + 2	90	98	90	278	93	95	98	98	292	97	95	95	95	285	95	855	95
cycloate + phenmedipham	2 + 6	100	100	98	298	99	100	100	100	300	100	99	100	98	297	99	895	99
cycloate + phenmedipham	4 + 0	80	90	80	250	83	75	85	80	240	80	95	95	95	285	95	775	86
cycloate + phenmedipham	4 + 2	98	98	98	294	98	98	99	98	295	98	100	99	100	299	99	888	99
cycloate + phenmedipham	4 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 0	95	97	95	287	96	95	97	95	287	96	95	97	95	287	96	861	96
cycloate + phenmedipham	6 + 2	98	97	98	293	98	98	99	100	297	99	100	100	100	300	100	890	99
cycloate + phenmedipham	6 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100

Appendix Table 13. Visual evaluation of percent barnyardgrass control (Stage I) - 1969 study at Hyslop.

Treatments	Rate lbs a.i./A	Barnyardgrass % control Observation I	II	III	Tot.	Avg	Barnyardgrass % control Observation I	II	III	Tot.	Avg	Barnyardgrass % control Observation I	II	III	Tot.	Avg	TOTAL	TOTAL AVG
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	20	15	20	35	22	30	30	40	100	33	40	15	20	75	25	210	23
cycloate + phenmedipham	0 + 6	30	30	30	90	30	50	50	60	160	53	50	40	30	120	40	370	41
cycloate + phenmedipham	.25 + 0	30	50	30	110	37	20	20	20	60	20	30	20	20	70	23	240	26
cycloate + phenmedipham	.25 + 2	50	60	60	170	57	70	50	60	180	60	70	50	60	180	60	530	50
cycloate + phenmedipham	.25 + 6	70	90	75	235	78	95	90	80	265	88	90	90	80	260	87	760	84
cycloate + phenmedipham	.50 + 0	30	50	30	110	37	30	30	30	90	30	40	50	50	140	47	340	38
cycloate + phenmedipham	.50 + 2	70	75	50	195	65	65	70	50	185	62	80	75	70	225	75	605	67
cycloate + phenmedipham	.50 + 6	95	98	90	283	94	85	90	70	245	82	95	95	90	280	93	808	90
cycloate + phenmedipham	1 + 0	40	40	40	120	40	30	40	30	100	33	30	40	30	100	33	320	36
cycloate + phenmedipham	1 + 2	50	60	60	170	57	70	85	80	235	78	60	75	60	195	65	600	67
cycloate + phenmedipham	1 + 6	95	90	80	265	88	98	95	90	283	94	90	95	85	270	90	818	91
cycloate + phenmedipham	2 + 0	90	90	80	260	87	90	90	90	270	90	98	95	98	291	90	821	91
cycloate + phenmedipham	2 + 2	100	99	100	299	100	100	99	98	297	99	100	100	100	300	100	896	100
cycloate + phenmedipham	2 + 6	100	100	100	300	100	100	99	100	299	100	100	100	100	300	100	899	100
cycloate + phenmedipham	4 + 0	95	95	95	285	95	100	98	100	298	99	100	99	98	297	99	880	98
cycloate + phenmedipham	4 + 2	100	100	100	300	100	100	99	100	299	100	100	99	100	299	100	898	100
cycloate + phenmedipham	4 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 0	100	98	98	296	99	100	98	100	298	99	100	98	100	298	99	892	99
cycloate + phenmedipham	6 + 2	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100

Appendix Table 14. Visual evaluation of percent mustard control (Stage I) - 1969 study at Hyslop.

Treatments	Rate lbs a.i./A	Mustard % control Observation I	II	III	Tot.	Avg	Mustard % control Observation I	II	III	Tot.	Avg	Mustard % control Observation I	II	III	Tot.	Avg	TOTAL	TOTAL AVG
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	0	0	0	0	0	0	0	0	0	0	5	10	10	25	8	25	2
cycloate + phenmedipham	0 + 6	20	10	30	60	20	40	40	50	130	43	50	40	60	150	50	340	37
cycloate + phenmedipham	.25 + 0	10	0	0	10	3	0	0	0	0	0	0	0	0	0	0	10	1
cycloate + phenmedipham	.25 + 2	0	10	10	20	6	0	0	0	0	0	0	0	0	0	0	20	2
cycloate + phenmedipham	.25 + 6	95	95	90	280	93	98	95	85	278	93	90	0	0	0	0	560	62
cycloate + phenmedipham	.50 + 0	15	10	10	35	12	0	10	0	10	3	0	0	0	0	0	45	5
cycloate + phenmedipham	.50 + 2	10	5	20	35	11	20	10	10	40	13	10	30	10	50	17	125	20
cycloate + phenmedipham	.50 + 6	95	90	70	255	85	50	70	60	180	60	90	95	80	265	88	700	78
cycloate + phenmedipham	1 + 0	5	0	0	5	1	0	0	0	0	0	5	0	0	5	1	10	1
cycloate + phenmedipham	1 + 2	15	10	10	35	12	10	20	20	50	16	20	20	20	60	20	145	24
cycloate + phenmedipham	1 + 6	98	95	95	288	96	85	85	90	260	87	99	99	100	298	99	846	94
cycloate + phenmedipham	2 + 0	0	0	0	0	0	5	0	0	5	1	0	0	0	0	0	5	1
cycloate + phenmedipham	2 + 2	20	40	40	100	33	45	20	20	85	28	40	40	50	130	43	315	35
cycloate + phenmedipham	2 + 6	90	90	85	265	88	95	90	90	275	91	95	90	85	270	90	810	90
cycloate + phenmedipham	4 + 0	10	10	10	30	10	10	20	10	40	13	1	10	20	30	10	100	11
cycloate + phenmedipham	4 + 2	90	90	80	260	87	80	65	60	205	68	90	90	85	265	88	730	81
cycloate + phenmedipham	4 + 6	98	98	98	294	98	90	98	98	286	95	100	100	100	300	100	880	98
cycloate + phenmedipham	6 + 0	10	10	20	40	13	20	20	10	50	17	30	10	30	70	23	160	18
cycloate + phenmedipham	6 + 2	95	97	95	287	96	80	85	75	240	80	95	95	90	280	93	807	90
cycloate + phenmedipham	6 + 6	98	99	100	297	99	98	100	98	296	99	100	100	100	300	100	893	99

Appendix Table 15. Visual evaluations of percent sugarbeet injury (Stage I) - 1969 study at Hyslop.

Treatments	Rate lbs a.i./A	Sugarbeets % injury Obs I	Obs II	Obs III	Total	Avg	Sugarbeets % injury Obs I	Obs II	Obs III	Total	Avg	Sugarbeets % injury Obs I	Obs II	Obs III	Total	Avg	Total	Total Avg
cyloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	1 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	1 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	1 + 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	2 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	2 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	2 + 6	0	0	5	5	1	0	0	0	0	0	0	0	0	0	0	5	0
cycloate + phenmedipham	4 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	4 + 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	4 + 6	0	0	0	0	0	0	0	0	0	0	0	0	5	5	21	5	0
cycloate + phenmedipham	6 + 0	0	0	0	0	0	0	5	0	5	21	0	0	0	0	0	5	0
cycloate + phenmedipham	6 + 2	0	0	0	0	0	10	5	0	15	5	0	0	0	0	0	15	1
cycloate + phenmedipham	6 + 6	0	0	10	10	3	10	5	0	15	5	30	25	20	75	25	100	11

Appendix Table 16. Visual evaluations of percent pigweed control (Stage II) - 1969 study at Hyslop.

Treatments	Rate lbs a. i. /A	Pigweed % control					Pigweed % control					Pigweed % control					TOTAL	TOTAL AVG
		Observation					Observation					Observation						
		I	II	III	Tot.	Avg	I	II	III	Tot.	Avg	I	II	III	Tot.	Avg		
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	40	30	20	90	30	30	20	20	70	23	10	10	15	36	12	196	22
cycloate + phenmedipham	0 + 6	50	40	30	120	40	60	50	40	150	50	40	40	40	120	40	390	43
cycloate + phenmedipham	.25 + 0	60	60	50	170	57	60	65	60	185	62	40	40	40	120	40	475	53
cycloate + phenmedipham	.25 + 2	50	70	60	180	60	60	75	70	205	68	50	60	70	180	60	565	63
cycloate + phenmedipham	.25 + 6	60	75	65	200	67	75	85	75	235	78	75	75	70	220	73	655	73
cycloate + phenmedipham	.50 + 0	60	60	40	160	53	45	60	40	145	48	25	30	30	85	28	390	43
cycloate + phenmedipham	.50 + 2	70	70	65	205	68	60	70	70	200	66	50	50	50	150	50	555	62
cycloate + phenmedipham	.50 + 6	75	70	65	210	70	70	80	80	230	77	70	75	70	215	72	655	73
cycloate + phenmedipham	1 + 0	50	60	70	180	60	50	60	50	160	53	40	50	50	140	47	480	53
cycloate + phenmedipham	1 + 2	70	70	80	220	73	60	80	70	210	70	70	70	70	210	70	640	71
cycloate + phenmedipham	1 + 6	80	80	85	245	82	80	85	85	250	83	85	85	90	260	87	755	84
cycloate + phenmedipham	2 + 0	80	85	85	250	83	60	70	60	190	63	60	60	60	180	60	620	68
cycloate + phenmedipham	2 + 2	85	90	85	260	87	80	85	85	250	83	80	75	70	225	75	735	82
cycloate + phenmedipham	2 + 6	90	95	90	275	92	80	90	90	260	87	90	90	85	265	88	800	89
cycloate + phenmedipham	4 + 0	90	95	85	270	90	90	90	90	270	90	90	95	90	275	92	815	91
cycloate + phenmedipham	4 + 2	95	95	95	280	93	95	95	95	285	95	98	97	98	293	98	858	95
cycloate + phenmedipham	4 + 6	95	95	90	280	93	99	99	98	296	99	98	99	98	295	98	871	97
cycloate + phenmedipham	6 + 0	100	100	99	299	100	98	99	98	295	98	95	95	95	285	95	879	98
cycloate + phenmedipham	6 + 2	100	100	100	300	100	100	100	100	300	100	99	99	98	296	99	896	100
cycloate + phenmedipham	6 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100

Appendix Table 17. Visual evaluations of percent barnyardgrass (Stage II) - 1969 study at Hyslop.

Treatments	Rate lbs a. i. /A	Observation I	II	III	Tot.	Avg	Observation I	II	III	Tot.	Avg	Observation I	II	III	Tot.	Avg.	TOTAL	TOTAL AVG
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	30	40	40	110	37	20	20	10	50	17	10	10	10	30	10	190	21
cycloate + phenmedipham	0 + 6	20	20	50	90	30	30	40	30	100	33	20	20	45	85	28	275	30
cycloate + phenmedipham	.25 + 0	0	0	10	10	3	0	0	10	10	3	0	0	10	10	3	30	3
cycloate + phenmedipham	.25 + 2	10	15	20	45	15	10	20	25	55	18	20	20	20	60	20	160	18
cycloate + phenmedipham	.25 + 6	20	20	25	65	22	40	40	45	125	42	40	40	40	120	40	230	26
cycloate + phenmedipham	.25 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 2	10	20	30	60	20	20	20	20	60	20	10	20	20	50	17	180	20
cycloate + phenmedipham	.25 + 6	0	10	10	20	6	30	30	15	75	25	40	50	35	125	42	221	25
cycloate + phenmedipham	1 + 0	70	70	60	200	66	60	60	50	190	63	50	60	50	160	53	550	61
cycloate + phenmedipham	1 + 2	90	95	85	270	90	75	75	70	220	73	80	80	85	245	82	735	82
cycloate + phenmedipham	1 + 6	90	95	85	270	90	80	90	80	250	83	95	95	95	285	95	805	89
cycloate + phenmedipham	2 + 0	90	90	80	260	87	80	80	80	240	80	85	80	80	245	82	745	83
cycloate + phenmedipham	2 + 2	99	100	98	297	99	95	99	95	289	96	95	95	95	285	95	871	97
cycloate + phenmedipham	2 + 6	100	99	100	299	100	100	99	98	297	99	100	99	98	297	99	893	99
cycloate + phenmedipham	4 + 0	90	99	90	279	93	95	95	90	280	93	98	95	95	288	96	847	94
cycloate + phenmedipham	4 + 2	100	100	100	300	100	100	100	100	300	100	100	99	100	299	100	899	100
cycloate + phenmedipham	4 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 0	100	100	100	300	100	98	99	98	295	98	98	95	98	291	90	886	98
cycloate + phenmedipham	6 + 2	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100

Appendix Table 18. Visual evaluations of percent mustard (Stage II) - 1969 study at Hyslop.

Treatments	Rate lbs a. i. /A	Mustard % control Observation I	II	III	Tot.	Avg	Mustard % control Observation I	II	III	Tot.	Avg	Mustard % control Observation I	II	III	Tot.	Avg	TOTAL	TOTAL AVG
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	10	40	40	90	30	30	40	40	110	37	70	50	50	70	56	370	43
cycloate + phenmedipham	0 + 6	40	40	40	120	40	75	75	80	230	77	180	80	85	245	81	595	66
cycloate + phenmedipham	.25 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.25 + 2	40	40	40	120	40	80	85	70	235	78	75	80	60	215	72	570	63
cycloate + phenmedipham	.25 + 6	75	80	85	240	80	100	100	100	300	100	98	99	98	295	98	835	92
cycloate + phenmedipham	.50 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	.50 + 2	95	80	90	265	88	40	80	70	194	63	90	80	80	250	83	705	78
cycloate + phenmedipham	.50 + 6	99	99	99	297	99	100	100	100	300	100	100	95	99	294	98	891	99
cycloate + phenmedipham	1 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	3	10	2
cycloate + phenmedipham	1 + 2	90	80	90	260	87	95	90	95	280	93	80	80	80	240	80	780	87
cycloate + phenmedipham	1 + 6	100	100	100	300	100	100	99	100	297	100	100	99	99	298	99	897	100
cycloate + phenmedipham	2 + 0	10	20	10	40	13	10	10	0	20	6	10	10	10	30	10	90	10
cycloate + phenmedipham	2 + 2	100	99	99	298	99	98	99	95	292	97	98	99	98	295	98	885	98
cycloate + phenmedipham	2 + 6	100	99	100	299	100	100	100	100	300	100	99	99	99	297	99	896	100
cycloate + phenmedipham	4 + 0	10	10	10	30	10	40	30	40	110	37	10	10	10	30	10	170	19
cycloate + phenmedipham	4 + 2	100	99	100	299	100	100	100	100	300	100	98	99	99	296	99	895	100
cycloate + phenmedipham	4 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100
cycloate + phenmedipham	6 + 0	70	80	60	210	75	40	100	30	110	37	40	30	35	105	35	425	47
cycloate + phenmedipham	6 + 2	100	100	98	298	99	100	100	100	300	100	100	100	100	300	100	899	100
cycloate + phenmedipham	6 + 6	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100	900	100

Appendix Table 19. Visual evaluations of percent sugarbeet injury and weed control of pigweed, mustard, and groundsel (Stage III) - 1969 study at Hyslop.

Treatments	Rate lbs a.i./A	Sugarbeets				Pigweed				Barnyardgrass				Mustard				Groundsel			
		I	II	III	Avg	I	II	III	Avg	I	II	III	Avg	I	II	III	Avg	I	II	III	Avg
cycloate + phenmedipham	0 + 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cycloate + phenmedipham	0 + 2	0	0	0	0	30	30	20	27	90	90	90	90	0	5	0	1	100	90	90	93
cycloate + phenmedipham	0 + 6	0	0	0	0	40	30	30	33	90	90	90	90	5	5	5	5	100	90	90	93
cycloate + phenmedipham	.25 + 0	0	0	0	0	20	10	10	13	0	20	10	10	5	0	5	3	0	0	0	0
cycloate + phenmedipham	.25 + 2	0	0	0	0	30	25	10	22	30	70	70	57	10	5	10	8	90	90	90	90
cycloate + phenmedipham	.25 + 6	0	0	0	0	50	35	20	35	90	95	93	10	10	15	12	90	90	90	90	90
cycloate + phenmedipham	.50 + 0	0	0	0	0	20	20	10	17	0	0	0	0	10	5	10	8	0	0	0	0
cycloate + phenmedipham	.50 + 2	0	0	0	0	30	30	10	23	30	20	75	42	10	10	10	10	90	90	90	90
cycloate + phenmedipham	.50 + 6	0	0	0	0	50	35	40	42	90	90	95	92	15	10	15	13	90	90	90	90
cycloate + phenmedipham	1 + 0	0	0	0	0	30	20	30	27	15	15	15	15	30	20	10	20	10	10	10	10
cycloate + phenmedipham	1 + 2	0	0	0	0	40	20	40	33	95	90	90	92	30	30	30	30	100	95	95	97
cycloate + phenmedipham	1 + 6	0	0	0	0	50	50	50	50	95	95	95	95	30	35	30	32	100	100	100	100
cycloate + phenmedipham	2 + 0	0	0	0	0	60	45	30	45	50	30	25	35	80	60	60	67	50	40	50	47
cycloate + phenmedipham	2 + 2	0	0	0	0	70	60	45	58	95	100	90	95	100	75	70	82	100	95	95	97
cycloate + phenmedipham	2 + 6	0	0	0	0	75	70	60	68	95	100	100	98	100	85	90	92	100	100	95	98
cycloate + phenmedipham	4 + 0	0	0	0	0	90	80	70	80	60	50	40	50	99	99	75	91	50	20	50	40
cycloate + phenmedipham	4 + 2	0	0	0	0	100	95	90	95	100	100	100	100	100	100	100	100	100	95	95	97
cycloate + phenmedipham	4 + 6	0	0	0	0	100	95	90	95	100	100	100	100	100	100	100	100	100	100	100	100
cycloate + phenmedipham	6 + 0	0	0	0	0	90	90	90	90	60	60	50	57	99	100	100	100	55	40	50	48
cycloate + phenmedipham	6 + 2	5	0	0	1	100	95	95	97	100	100	100	100	100	100	100	100	100	95	100	98
cycloate + phenmedipham	6 + 6	10	0	0	3	100	95	98	98	100	100	100	100	100	100	100	100	100	100	100	100

Appendix Table 20. Fresh weights in grams (Stage I) - 1969 study at Hyslop.

Treatments	Rate lbs a. i. /A	Sugarbeets I	II	III	Avg	Pigweed I	II	III	Avg	Barnyardgrass I	II	III	Avg
cycloate + phenmedipham	0 + 0	618	568	4.45	544	733	667	4.83	628	592	732	3.69	564
cycloate + phenmedipham	0 + 2	993	1301	8.10	1035	632	408	5.72	537	556	606	2.82	481
cycloate + phenmedipham	0 + 6	873	888	8.34	865	337	300	3.08	315	304	164	2.54	241
cycloate + phenmedipham	.25 + 0	293	1091	5.68	651	147	809	6.08	524	250	1042	3.70	554
cycloate + phenmedipham	.25 + 2	802	1381	9.37	1040	254	568	4.74	432	373	619	3.44	445
cycloate + phenmedipham	.25 + 6	970	1028	10.89	1029	126	240	2.85	217	166	113	0.72	117
cycloate + phenmedipham	.50 + 0	459	771	5.11	580	159	545	6.24	443	230	402	1.93	275
cycloate + phenmedipham	.50 + 2	863	1218	9.36	1006	352	587	3.79	439	477	550	2.05	411
cycloate + phenmedipham	.50 + 6	742	1275	5.50	856	-	309	0.34	114	70	185	0.42	99
cycloate + phenmedipham	1 + 0	608	1207	5.01	772	343	699	3.34	459	211	439	2.83	311
cycloate + phenmedipham	1 + 2	1147	1867	11.13	1376	317	218	4.19	318	334	29	2.84	216
cycloate + phenmedipham	1 + 6	994	1034	8.40	956	144	209	2.06	186	59	3	.62	41
cycloate + phenmedipham	2 + 0	716	888	8.32	812	230	467	3.57	351	53	16	1	23
cycloate + phenmedipham	2 + 2	914	1477	8.33	1075	26	-	0.41	22	-	-	-	0
cycloate + phenmedipham	2 + 6	816	1202	8.05	941	-	-	-	0	-	-	-	0
cycloate + phenmedipham	4 + 0	842	1517	8.39	1066	101	578	0.21	233	42	-	3.00	114
cycloate + phenmedipham	4 + 2	1170	1976	10.87	1411	-	-	-	0	-	-	-	0
cycloate + phenmedipham	4 + 6	769	877	7.17	788	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 0	964	1697	11.48	1270	-	45	0.33	26	-	-	-	0
cycloate + phenmedipham	6 + 2	858	1515	10.88	1154	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 6	594	988	8.37	806	-	-	-	0	-	-	-	0

Appendix Table 21. Dry weights in grams (Stage I) - 1969 study at Hyslop.

Treatments	Rate lbs a.i./A	Sugarbeets I	Sugarbeets II	Sugarbeets III	Sugarbeets Avg	Pigweed I	Pigweed II	Pigweed III	Pigweed Avg	Barnyardgrass I	Barnyardgrass II	Barnyardgrass III	Barnyardgrass Avg
cycloate + phenmedipham	0 + 0	69	68	70	69	160	150	110	140	101	116	74	97
cycloate + phenmedipham	0 + 2	109	145	103	119	32	95	125	75	84	88	54	75
cycloate + phenmedipham	0 + 6	109	101	103	104	68	59	62	63	53	29	46	43
cycloate + phenmedipham	.25 + 0	34	120	83	79	54	170	169	131	71	70	90	77
cycloate + phenmedipham	.25 + 2	111	135	131	126	52	104	133	96	67	90	63	73
cycloate + phenmedipham	.25 + 6	109	123	141	124	24	50	68	47	27	20	15	21
cycloate + phenmedipham	.50 + 0	70	89	61	73	41	125	138	101	46	75	37	53
cycloate + phenmedipham	.50 + 2	106	128	117	117	72	114	79	88	76	75	37	63
cycloate + phenmedipham	.50 + 6	90	127	70	96	38	57	9	35	13	30	9	35
cycloate + phenmedipham	1 + 0	64	120	66	83	76	146	82	101	40	77	49	56
cycloate + phenmedipham	1 + 2	124	117	138	126	60	41	94	65	53	6	52	37
cycloate + phenmedipham	1 + 6	110	115	110	112	27	40	44	37	10	2	13	8
cycloate + phenmedipham	2 + 0	86	125	100	104	50	106	75	77	11	4	1	5
cycloate + phenmedipham	2 + 2	101	152	104	119	6	-	10	5	-	-	-	0
cycloate + phenmedipham	2 + 6	93	128	102	108	-	-	-	0	-	-	-	0
cycloate + phenmedipham	4 + 0	109	160	101	123	23	110	5	46	10	-	1	4
cycloate + phenmedipham	4 + 2	127	155	129	137	-	-	-	0	-	-	-	0
cycloate + phenmedipham	4 + 6	85	87	89	88	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 0	112	156	136	135	-	10	9	6	-	-	-	0
cycloate + phenmedipham	6 + 2	97	150	131	126	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 6	70	99	103	91	-	-	-	0	-	-	-	0

Appendix Table 22. Fresh weights in grams (Stage II) - 1969 study at Hyslop.

Treatments	Rate lbs a. i. /A	Sugarbeets I	Sugarbeets II	Sugarbeets III	Sugarbeets Avg	Pigweed I	Pigweed II	Pigweed III	Pigweed Avg	Barnyardgrass I	Barnyardgrass II	Barnyardgrass III	Barnyardgrass Avg
cycloate + phenmedipham	0 + 0	247	553	150	317	623	386	410	473	400	349	103	284
cycloate + phenmedipham	0 + 2	655	876	176	569	625	518	287	477	317	297	143	252
cycloate + phenmedipham	0 + 6	930	1033	210	724	688	429	225	447	650	316	133	366
cycloate + phenmedipham	.25 + 0	654	740	77	490	324	375	572	424	475	625	134	411
cycloate + phenmedipham	.25 + 2	843	695	163	567	550	558	676	595	292	468	164	308
cycloate + phenmedipham	.26 + 6	1180	750	95	675	425	400	667	497	382	283	144	270
cycloate + phenmedipham	.50 + 0	830	644	248	574	405	292	525	407	610	361	244	405
cycloate + phenmedipham	.50 + 2	833	830	272	645	463	590	447	500	255	407	248	303
cycloate + phenmedipham	.50 + 6	737	674	484	632	430	399	183	321	312	202	46	187
cycloate + phenmedipham	1 + 0	1035	753	426	732	600	569	661	610	87	178	194	153
cycloate + phenmedipham	1 + 2	1137	1017	683	946	557	477	432	489	28	263	144	145
cycloate + phenmedipham	1 + 6	1385	964	596	982	604	380	346	443	80	140	24	81
cycloate + phenmedipham	2 + 0	890	822	668	793	145	355	463	321	43	71	25	46
cycloate + phenmedipham	2 + 2	673	1139	674	829	85	366	389	280	-	-	26	9
cycloate + phenmedipham	2 + 6	1085	1216	818	1040	262	269	320	284	-	-	-	0
cycloate + phenmedipham	4 + 0	1110	1298	782	1063	112	96	129	112	-	33	-	11
cycloate + phenmedipham	4 + 2	1060	1204	881	1048	25	32	75	44	-	-	-	0
cycloate + phenmedipham	4 + 6	1280	1293	815	1129	95	28	40	54	-	-	-	0
cycloate + phenmedipham	6 + 0	1090	993	977	1020	-	40	25	22	-	-	-	0
cycloate + phenmedipham	6 + 2	647	917	1025	863	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 6	740	847	385	657	-	-	-	0	-	-	-	0

Appendix Table 23. Dry weights in grams (Stage I) - 1969 study at Hyslop.

Treatments	Rates lbs a. i. /A	Sugarbeets I	Sugarbeets II	Sugarbeets III	Sugarbeets Avg	Pigweed I	Pigweed II	Pigweed III	Pigweed Avg	Barnyardgrass I	Barnyardgrass II	Barnyardgrass III	Barnyardgrass Avg
cycloate + phenmedipham	0 + 0	46	70	23	46	162	90	132	128	85	66	39	63
cycloate + phenmedipham	0 + 2	75	103	27	68	146	114	94	118	58	51	38	49
cycloate + phenmedipham	0 + 6	99	114	35	83	135	87	60	94	85	49	31	55
cycloate + phenmedipham	.25 + 0	57	104	12	58	75	91	48	71	127	91	47	88
cycloate + phenmedipham	.25 + 2	118	80	23	74	123	126	136	128	72	75	35	61
cycloate + phenmedipham	.25 + 6	84	98	13	65	84	85	40	70	65	33	30	43
cycloate + phenmedipham	.50 + 0	93	97	35	75	93	70	136	100	99	99	53	84
cycloate + phenmedipham	.50 + 2	102	93	34	76	92	135	112	113	58	70	49	59
cycloate + phenmedipham	.50 + 6	150	74	70	98	84	63	44	64	50	35	9	63
cycloate + phenmedipham	1 + 0	113	94	54	87	124	140	127	130	17	32	32	27
cycloate + phenmedipham	1 + 2	125	118	84	109	99	107	127	111	13	46	27	29
cycloate + phenmedipham	1 + 6	82	116	80	93	97	78	75	83	11	22	3	12
cycloate + phenmedipham	2 + 0	99	105	99	101	28	77	111	72	5	10	9	8
cycloate + phenmedipham	2 + 2	104	153	98	118	15	71	91	59	-	-	6	2
cycloate + phenmedipham	2 + 6	113	147	96	119	13	49	67	43	-	-	-	0
cycloate + phenmedipham	4 + 0	27	160	94	94	22	16	30	23	-	2	-	1
cycloate + phenmedipham	4 + 2	170	138	100	136	2	2	13	6	-	-	-	0
cycloate + phenmedipham	4 + 6	172	137	100	136	1	2	7	3	-	-	-	0
cycloate + phenmedipham	6 + 0	114	130	134	126	-	5	2	2	-	-	-	0
cycloate + phenmedipham	6 + 2	70	120	126	105	-	-	-	0	-	-	-	0
cycloate + phenmedipham	6 + 6	64	102	102	89	-	-	-	0	-	-	-	0

Appendix Table 24. Wax extract weights of cycloate treated cabbage.

Treatment	Rate lb a.i./A	Weight in Milligrams				
		Rep I	Rep II	Rep III	Rep IV	Avg
untreated	0	.190	.198	.195	.193	.194
cycloate	.25	.188	.192	.189	.191	.190
cycloate	.50	.193	.196	.184	.193	.192
cycloate	1	.176	.164	.174	.175	.172
cycloate	2	.151	.151	.153	.149	.151
cycloate	4	.139	.133	.134	.135	.135

C.V. = .3%

LSD .05 = .004
LSD .01 = .015

Analysis of Variance of Data in Appendix Table 24

Source	df	SS	MS	F
Reps	3	.000060	.000002	
Trts	5	.011917	.002383	14.89**
R x T	15	.000240	.000160	
Total	23	.012163		

Appendix Table 25. Wax extract weight of cycloate treated sugarbeets.

Treatment	Rate lbs a.i./A	Weights in Milligrams				
		Rep I	Rep II	Rep III	Rep IV	Avg
untreated	0	.008	.012	.008	.014	.011
cycloate	.25	.013	.009	.012	.013	.012
cycloate	1	.007	.009	.012	.009	.009
cycloate	4	.007	.014	.005	.009	.009
cycloate	6	.009	.008	.014	.013	.011

C.V. = 5.2%

Analysis of Variance of Data in Appendix Table 25

Source	df	SS	MS	F
Reps	3	.000550		
Trts	5	.000733	.000183	1.60 NS
R x T	15	.001370	.000114	
Total	23	.000146		

Appendix Table 26. Wax extract weights of cycloate treated pigweed.

Treatments	Rate lb a.i./A	Weight in Milligrams				
		Rep I	Rep II	Rep III	Rep IV	Avg
untreated	0	.038	.022	.036	.013	.027
cycloate	.25	.009	.013	.012	.012	.012
cycloate	1	.020	.012	.033	.033	.025
cycloate	4	.014	.020	.013	.020	.016

C.V. = 9.4%

Analysis of Variance of Data in Appendix Table 26

Source	df	SS	MS	F
Reps	3	.002256		
Trts	3	.002963	.000987	1.08 NS
R x T	9	.008199	.000911	
Total	15	.013418		

Appendix Table 27. Wax extract weights of cycloate treated mustard.

Treatment	Rate lb a.i./A	Weights in Milligrams				
		Rep I	Rep II	Rep III	Rep IV	Avg
untreated	0	.472	.498	.510	.512	.498
cycloate	.25	.480	.502	.529	.511	.506
cycloate	1	.501	.494	.473	.479	.487
cycloate	4	.485	.487	.462	.469	.476

C.V. = 6.8%

Analysis of Variance of Data in Appendix Table 27

Source	df	SS	MS	F
Reps	3	1.288751		
Trts	3	1.291099	.430366	1.50 NS
R x T	9	2.574602	.286066	
Total	15	.005248		