Chemical Weed Control in Peas, Sweet Corn, and Beets Grown For Processing

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Cover plate shows a dense stand of wild mustard growing in a field of canning peas and an area where the mustard has been eliminated with Dow Selective Weed Killer. (Photo by R. A. Wesselmann)

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CHEMICAL WEED CONTROL IN PEAS, SWEET CORN, AND BEETS GROWN FOR PROCESSING

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ABSTRACT

POST-EMERGENCE chemical weed control was studied in peas, sweet corn, and beets grown for processing.

Peas were sprayed with aqueous solutions nearly saturated with sodium chloride (common salt) or a mixture of salt and sodium nitrate. Aqueous sprays of ammonium dinitro ortho secondary butyl phenate were mixed at several concentrations and applied at several rates to the acre. A similar procedure was followed in testing potassium cyanate. Calcium cyanamid dust was spread with ground equipment and with an airplane. Only one application of a weedicide was made.

A small portable pea viner was designed and used for vining small samples in the field.

Wild mustard, *Brassica arvensis,* was controlled with each chemical. The destruction of wild mustard, lamb's quarters, *Chenopodium album,* red-root, *Amaranthus retroflexus,* and ragweed, *Ambrosia* sp., was best accomplished with dinitro ortho secondary butyl phenate.

Chemical weed control in Golden Cross Bantam sweet corn involved a study of amounts of 2,4–D to the acre, time of application in relation to the growth of the corn, cultivation in conjunction with spraying, and response of corn and weeds to esters versus amine salts of 2,4–D.

Sprays delivering 0.6 to 0.8 pound of 2,4–D acid equivalent to the acre effectively controlled the broadleaved weeds. Sprays applied when the corn was breaking ground and up to 8 inches tall appeared

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to affect the corn the least. Similar sprays applied when the corn was 2 feet tall effectively controlled the weeds without adversely affecting the yields. Sweet corn yields were extremely low where annual grasses came in on areas that were weeded with 2,4–D but never cultivated. The amine salts of 2,4–D used at ¾ pound to the acre were effective in controlling the weeds and did not have the highly objectionable feature of volatility that is characteristic of most ester formulations.

Beets were chemically weeded with sprays of sodium chloride (common salt) and of salt plus sodium nitrate. The foliage of beets, mustard, ragweed, red-root, and smartweed became flaccid within 20 minutes after spraying. The beets recovered in a few hours, whereas the weeds and annual grasses not over 1 inch tall were killed. Beets in the cotyledon stage were also killed. Even though lamb's quarters and purslane were not injured, the elimination of the other species justified the practice. The salt sprays were concentrated in an 8-inch band directly on the row.

INTRODUCTION

WEED control with chemicals has been in practice on a limited scale for centuries where the object was to destroy all vegetation. Ashes, salt, and smelter waste appear to have been among the early chemicals used, according to Robbins, *et al.* (9).[2] Even though the selective herbicidal action of some chemicals, such as copper sulfate, copper nitrate, and iron sulfate, was recognized as early as 1896 by Bonnet and in 1897 by Duclos, as cited by Robbins, *et al.* (9), the use of such chemicals was largely confined to the control of broadleaved weeds in grain fields (1,4). In 1904, Stone (13) reported that chemical sprays of copper sulfate were effective against mustard growing in corn, peas, and sugar beets.

The preliminary work of Ball and French (2) on weeding onions with sulfuric acid stimulated an interest in chemical weeding in the rapidly expanding vegetable industry.

The weeding of carrots on the West Coast with stove oil, reported by Raynor (7) and further investigated in the East by Sweet, *et al.* (14) and by Lachman (6), placed chemical weed control in carrots on a sound basis.

The producer of vegetables for processing usually grows many acres of only a few kinds of vegetables; and for efficiency in harvesting with heavy machinery, his operations are geared to mass production. The control of a heavy stand of wild mustard in canning

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[2]Reference is to Literature Cited, page 37.

peas, as illustrated on the cover page, shows clearly that weed competition can be eliminated. Under such growing conditions the destruction of one or two weed species justifies a chemical control measure.

The purpose of the study reported here was to determine which chemical or chemicals could be used to weed peas, sweet corn, and beets and yet not reduce the market value of the crop. Each crop is discussed separately because the weed problem and practical control measures differ for each crop.

MATERIALS USED

Materials used in the experiments included sodium chloride or common salt, sodium nitrate, sodium dichromate, and a number of commercial weedicides. Among the last-mentioned materials were the following:

Aero cyanamid, calcium cyanamid dust, American Cyanamid Company, 30 Rockefeller Plaza, New York City.

Aero cyanate, potassium cyanate, American Cyanamid Company, 30 Rockefeller Plaza, New York City.

Dow Selective Weed Killer, ammonium dinitro ortho secondary butyl phenate, Dow Chemical Company, Midland, Mich.

Sinox W, ammonium dinitro ortho secondary butyl phenate, Standard Agricultural Chemicals, Hoboken, N. J.

Chipman Amine, equivalent to 40 per cent 2,4–D acid, The Chipman Chemical Company, Inc., Bound Brook, N. J.

Dow Formula 40, equivalent to 40 per cent 2,4–D acid, Dow Chemical Company, Midland, Mich.

Esterone 44, equivalent to 37 per cent 2,4–D acid, Dow Chemical Company, Midland, Mich.

Weedone Concentrate 48, equivalent to 31.2 per cent 2,4–D acid, American Chemical Paint Company, Ambler, Pa.

WEED CONTROL IN PEAS

Wild mustard, *Brassica arvensis,* is the most common weed occurring in canning pea acreages in New York State. In some of the pea-growing areas the stand of mustard is so thick that pea yields are materially reduced by the competition of the weed. Under these conditions some pea growers have omitted peas from their rotation but have not solved their weed problem since mustard is also troublesome in their spring grains. The canner also has a stake in this matter because the mustard increases the tonnage of green material to be vined by as much as 30 to 50 per cent, and consequently increases the vining time per ton of shelled peas obtained.

Selective weeding of peas with Sinox was proposed by Westgate and Raynor (15), and more recently the use of dinitro compounds for weeding peas has been recommended by Raynor (8) and Barrons and Grigsby (3). Unpublished results of studies made by the Vegetable Crops Department of the Cornell University Agricultural Experiment Station at Ithaca indicated that severe burning of pea foliage frequently occurred where the dinitro compounds had been used in New York in accordance with the recommendations for other regions.

The purpose of the present study was to determine if a suitable material was available for weeding canning peas in New York.

EXPERIMENTS IN 1947

A screening test for selective weed killers for peas was begun in the greenhouse in 1947. Peas showed a tolerance to sprays of concentrated solutions of sodium chloride, sodium nitrate, a mixture of these two salts, Sinox–W, and Dow Selective Weed Killer, and to Aero cyanamid dust, whereas wild mustard was effectively controlled. Peas also showed considerable tolerance to very dilute sprays of 2,4–D.

Field experiments were conducted in 1947, 1948, and 1949 to determine the effectiveness of these chemicals on the control of wild mustard and other weeds in canning peas.

In cooperation with two pea growers, two experimental sites 72 × 72 feet were chosen on land that was normally heavily infested with mustard. Experiment I was planted to Surprise and Experiment II to Pride.

All weedicide materials were applied with hand-operated equipment to give complete coverage when the peas were 4 to 8 inches tall. Mustard was not as abundant as had been anticipated. However, the stand of lamb's quarters, *Chenopodium album,* and redroot, *Amaranthus retroflexus,* was heavy. The method of analysis of variance was used in interpreting the data from all weed control experiments.

The weedicides used, the weight of shelled peas, and the weight of all weeds are presented in Table 1.

TABLE 1.—THE EFFECT OF SEVEN WEEDICIDES ON THE YIELD OF SHELLED PEAS AND ON THE CONTROL OF WEEDS, 1947.

TREATMENT No.	CHEMICAL USED	RATE PER ACRE	WATER, GALS.	YIELDS PER ACRE: EXP. I, SURPRISE: Pounds shelled peas	YIELDS PER ACRE: EXP. I, SURPRISE: Pounds weeds	YIELDS PER ACRE: EXP. II, PRIDE: Pounds shelled peas
1	Sodium nitrate	200 lbs.	100	1,500	3,480	1,740
2	Sodium chloride	200 lbs.	100	1,410	2,250	1,820
3	Sodium chloride and sodium nitrate	120 lbs. 80 lbs.	100	1,330	2,780	1,900*
4	Sodium dichromate	16.6 lbs.	100	910	2,100	1,810†
5	Dinitro (Dow Selective)	3 pts.	100	1,230	1,100	1,840
6	Dinitro (Sinox-W)	6 pts.	100	1,100	760	1,810
7	Calcium cyanamid (Aero cyanamid dust)	75 lbs.	Dust	1,360	2,440	1,700
8	None	——	——	1,450	3,140	1,700
L.S.D. 5 per cent level..........				250	840	N.S.‡

*Sodium chloride was used at 166 pounds and sodium nitrate at 124 pounds.
†Sodium dichromate was used at 8.3 pounds plus 83 pounds of sodium nitrate.
‡N.S. means differences are not significant.

On the basis of the response of the weeds and peas to the seven weed control measures used in experiment I, the amount of chemicals in treatment 3 was increased in experiment II, while the composition of treatment 4 was materially modified as indicated in the footnote to Table 1. The 16.6 pounds of sodium dichromate burned the pea foliage and stems severely, whereas the mixture of salts in treatment 3 of experiment I gave very poor weed control.

It is significant that the dinitro compounds were the only chemical treatments that gave a satisfactory control of weeds without reducing the yield of shelled peas when compared with the untreated peas. Some burning of the peas resulted in experiment I from the use of both dinitro formulations. The sodium chloride spray (treatment 2) gave a statistically significant reduction in weed growth without modifying the yield of peas, but weed control was still unsatisfactory from the practical standpoint. In experiment II the weight of weeds was not obtained.

In addition to these replicated treatments Aero cyanamid was applied by airplane to a field of peas heavily infested with mustard, lamb's quarters, and red-root. The cyanamid dust was applied at 50, 75, and 150 pounds to the acre. The application was made in the early morning while the weeds and peas were still heavy with dew.

Most of the mustard plants were in the two true-leaf stage of development. The kill of weeds resulting from this dusting was rapid. When Aero cyanamid is effective as a weed killer the lower leaves of the pea plants are frequently burned to a crisp yellow color. Even so, the dusted strips at the left in Fig. 1 made an excellent crop in contrast to the untreated area. Yield records were not taken from this dusted strip because lodging of the peas made it impractical to mow them according to treated areas.

FIG. 1.—Peas at the left are free of mustard as a result of dusting with 100 pounds per acre of Aero cyanamid, while the untreated area on the right is heavy with mustard plants in full bloom.

EXPERIMENTS IN 1948

The study was continued in 1948 with five treatments in random order in each of five blocks in a field of Thomas Laxton peas. Each plot was 25 × 200 feet. The treatments and rates were as follows:

1, Ammonium dinitro ortho secondary butyl phenate (Dow Chemical Co. formulation), 7 pints in 70 gallons of water per acre as recommended by the manufacturer

2, Sodium chloride, 160 pounds in 80 gallons of water per acre

3, Sodium chloride, 128 pounds, plus sodium nitrate, 96 pounds, in 80 gallons of water per acre

4, Aero cyanamid dust, 75 pounds per acre

5, No treatment

A tractor-mounted sprayer with a 12-foot boom was used instead of the hand-operated equipment in order to have uniform spray coverage and to operate on a practical commercial basis. The tricycle-type tractor ran over the peas directly after the spray was applied and also over the unsprayed checks. A small gear pump driven through the tractor power-take-off shaft served to pump the solutions. Fan-type spray nozzles[3] were mounted, 18 inches on center, along the 12-foot boom and calibrated at 50 pounds pressure except for the concentrated salt sprays where only 20 pounds pressure was used. The cyanamid dust was applied with a self-propelled power duster. All treatments were applied when the peas were 4 to 8 inches tall. At this time the mustard was in the four true-leaf stage of growth. Climatic conditions were cloudy, cool, and wet prior to, during, and after treatment.

When the peas were prime for canning, the vines on each plot were cut with a sickle from within two frames each 3 × 9 feet. The small portable pea viner shown in Fig. 2 was used for threshing the

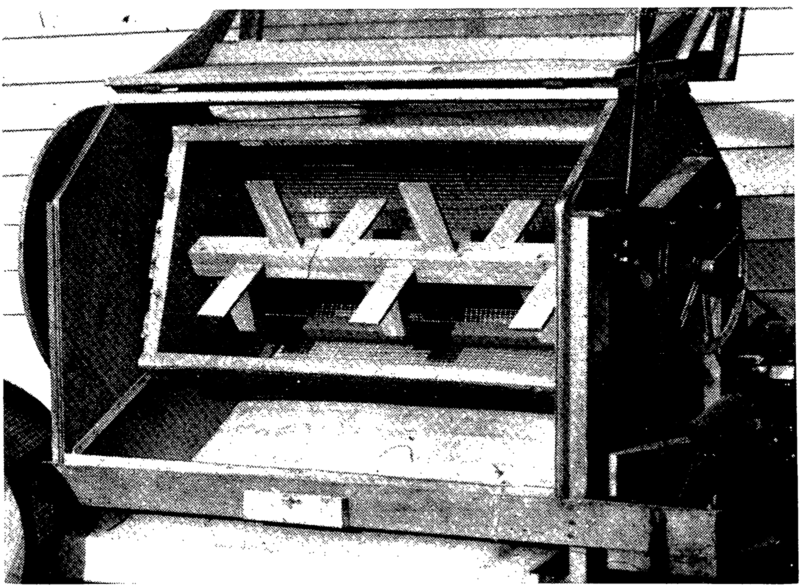

FIG. 2.—Portable gas engine-powered pea viner used for shelling peas.

[3]Spraying Systems Company, Bellwood, Ill.

peas from the vines. Records were taken on the total weight of green matter cut per plot and on the weight of mustard plants after separating the weeds from the pea vines. Tenderometer readings were also obtained on each sample of shelled peas. Yield records were based on the average weight of shelled peas obtained from the two 27 square foot samples in each of the five replicates. Yield records and tenderometer reading for the five treatments are presented in Table 2, together with the tonnage of mustard produced.

TABLE 2.—EFFECT OF WEEDICIDES ON YIELD AND MATURITY OF PEAS AND ON GROWTH OF MUSTARD, 1948.

TREATMENT	RATE PER ACRE		MUSTARD, TONS PER ACRE *	YIELD, LBS. PER ACRE	TENDEROMETER READING
	Chemical	Water, gals.			
1, Dow Selective.......	7 pts.	70	0.0	3,090	115
2, Sodium chloride.....	160 lbs.	80	3.5	2,580	110
3, Sodium chloride plus sodium nitrate.....	128 & 96 lbs.	80	3.0	2,450	110
4, Aero cyanamid......	75 lbs.	Dust	2.6	2,300	107
5, None	———	——	5.5	2,490	107
L.S.D. 5 per cent level..			1.3	485	3.8

*Weight records taken to the nearest ¼ pound from 27 square foot samples.

The data show that the average yield of shelled peas taken from the Dow Selective spray treatment was 3,090 pounds per acre as compared to 2,490 pounds on the untreated plots. The statistically significant increase in yield becomes even more significant from the practical standpoint when it is noted that there was an average of 5.5 tons of mustard per acre on the untreated area and practically none on the plots sprayed with the dinitro compound. Each of the other treatments reduced the tonnage of mustard significantly below that of the check without affecting the yield of peas. Undoubtedly some compensation should be made for the fact that the higher yields are associated with the higher tenderometer readings. Also, it should be noted that the check treatment was run over by a tractor, thus equalizing the treatment of all plots except for omission of weedicides on the check plot. In addition, the weedicidal value of potassium cyanate was tested in several weedy pea fields with considerable success, as measured by observation.

EXPERIMENTS IN 1949

Six experiments were conducted with four canning pea growers who ordinarily had a heavy stand of mustard. Three experiments dealt with chemical pre-emergence weeding practices but did not result in satisfactory mustard control and are not reported here. In order to use several sprays and a more precise experimental arrangement of plots and in order not to have to drive over the peas but once, a bank of spray booms fed by separate gear pumps was mounted on the tractor. All plots were 12 × 30 feet arranged in a Latin square design where possible.

Experiment I consisted of three replicates of 11 spray treatments designed to gain information on how to use potassium cyanate.

The treatments per acre were as follows:

1, Aero cyanate sprayed at 8, 10, 12, and 14 pounds in 25 or 75 gallons of water

2, Dow Selective Weed Killer sprayed at 7 pints in 25 or 75 gallons of water

3, Sodium chloride sprayed at the rate of 320 pounds in 160 gallons of water

4, Sodium chloride sprayed at the rate of 256 pounds plus sodium nitrate at 192 pounds in 160 gallons of water

The amine salt of 2,4–D was used at ¼ pound acid equivalent to the acre in a separate study. All sprays were applied at 35 pounds pressure except for the sodium chloride and sodium nitrate mixtures. Twenty pounds pressure was all that could be developed where eight nozzles were delivering at the rate of 160 gallons to the acre. Low temperatures in the range of 30° to 50° F and very dry weather prevailed prior to, during, and for several days after each experiment was sprayed. When the peas were mature for processing, the pea samples were taken from a 45 square foot area in each plot. Three frames 3 × 5 feet each were placed end-to-end yet off-set by their widths so that the sample was drawn from a diagonal pattern across each plot. The treatments used in experiment I and the yields obtained are presented in Table 3.

It is evident from the 0.5 ton of mustard cut per acre that 8 pounds of Aero cyanate per acre was not enough to kill the mustard under the conditions of this experiment. This conclusion was also supported by field observations. Aero cyanate used at the rate of 12 pounds in 75 gallons of water per acre (treatment 6) gave ex-

TABLE 3.—EFFECT OF FOUR WEEDICIDAL MATERIALS ON THE PRODUCTIVITY OF PEAS AND CONTROL OF MUSTARD, 1949.

TREATMENT	RATE PER ACRE	GALLONS OF WATER PER ACRE	SHELLED PEAS, LBS. PER ACRE	MUSTARD, TONS PER ACRE
1, Aero cyanate	8 lbs.	25	800	0.5
2, Aero cyanate	10 lbs.	25	1,070	—
3, Aero cyanate	12 lbs.	25	1,030	—
4, Aero cyanate	14 lbs.	25	1,120	—
5, Aero cyanate	10 lbs.	75	950	—
6, Aero cyanate	12 lbs.	75	1,220	—
7, Aero cyanate	14 lbs.	75	950	—
8, Dow Selective	7 pts.	75	1,220	—
9, Sodium chloride	320 lbs.	160	1,350	—
10, Sodium chloride and sodium nitrate	256 lbs. 192 lbs.	160	1,070	—
11, None	—	—	290	1.5
L.S.D. 5 per cent level			520	

cellent control of mustard, as is shown in Fig. 3. It seems pertinent to point out that a large portion of the pea acreage in New York failed in 1949 as a result of very low rainfall, high temperatures, and a high evaporation rate.

It is obvious that the extremely low yield of 290 pounds of peas per acre on the check plot was largely the result of the competition from the 1.5 tons of mustard growing in the same area. In this experiment the soil was so dry at pea harvest that 10 to 20 per cent

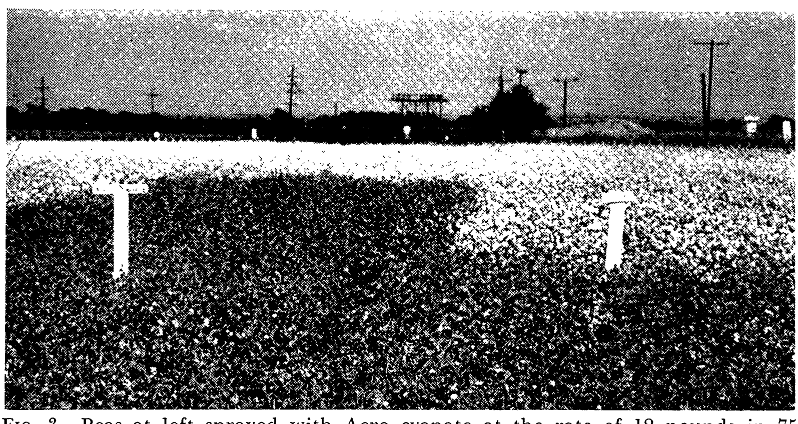

FIG. 3.—Peas at left sprayed with Aero cyanate at the rate of 12 pounds in 75 gallons of water per acre in contrast to untreated peas obscured by mustard in the check plot at right and in the background. (Photo by R. A. Wesselmann)

of the foliage of both the peas and the mustard was dried to a crisp condition. This accounts for the fact that such a dense stand of mustard as is shown in the check plots in Fig. 4 weighed only 1.5 tons per acre when the peas were harvested. Under average growing conditions this stand of mustard would have contributed at least 5 ton of extra, useless green matter to be handled and vined at pea harvest time.

FIG. 4.—Experimental area showing dense stand of wild mustard in peas in the three untreated plots. Experimental area is surrounded by mustard in bloom. (Photo by R. A. Wesselmann)

Experiments II and III were laid out on a 7 × 7 Latin square design. It developed that mustard was not a problem in experiment III. Medium red clover was sown with the peas at this location as is the practice in some regions. In Table 4 the treatments for the two experiments are shown, as well as the yield of peas, yield of mustard, and percentage of clover stand at pea harvest.

Statistically, the average yields of shelled peas per plot for the seven treatments were not significantly different. It is of interest to note, however, that in both experiments the yield of peas from the sprayed plots was generally higher than from the check plots. Where mustard was present, any one of the six chemical sprays gave satisfactory control. It is of practical significance that where a chemical spray was applied no measurable quantity of mustard persisted,

TABLE 4.—YIELD OF SHELLED PEAS AND TONNAGE OF MUSTARD PRODUCED FROM SPRAYED VERSUS NONSPRAYED PEAS, 1949.*

Treatment	Rate per acre		Experiment II, Surprise		Experiment III, Pride	
	Chemical	Water, gals.	Shelled peas, lbs. per acre	Mustard, tons per acre	Shelled peas, lbs. per acre	Clover, per cent remaining
1, Dow Selective......	7 pts.	25	1,460	0	1,920	15
2, Dow Selective......	7 pts.	75	1,470	0	1,940	50
3, Aero cyanate†......	12 lbs.	25	1,740	0	1,700	30
4, Aero cyanate†......	12 lbs.	75	1,610	0	1,640	15
5, Sodium chloride....	320 lbs.	160	1,590	0	1,510	0
6, Sodium chloride and sodium nitrate....	256 lbs. 192 lbs.	160	1,610	0	1,430	5
7, None..............	———	——	1,160	2.7	1,470	100

*Differences in yield of peas not significant at the 5 per cent level.
†Aero cyanate in experiment III used at 14 pounds per acre.

whereas the check areas in experiment II produced mustard at the rate of 2.7 tons per acre.

Table 4 shows that during the dry season of 1949, 50 per cent of the clover sown with peas persisted after spraying with a reduced concentration of Dow Selective Weed Killer. Aero cyanate was the next best treatment, with 30 per cent of the clover remaining at pea harvest time. Another interesting relationship among the numbers in the last column is that dilution of the dinitro spray from 25 to 75 gallons of water to the acre resulted in a higher percentage of clover remaining, while diluting the potassium cyanate spray further reduced the stand of clover. It should be emphasized that these observations on stand of clover represent only one season's results and may not reflect a true picture of the effect of these weed killers on the persistence of clover.

Throughout these studies weeds other than mustard common in this region were encountered. All were satisfactorily controlled except lamb's quarters growing on the plots sprayed with salt or salt plus sodium nitrate. The saline sprays are not satisfactory as selective weedicides where lamb's quarters is the predominant weed.

Peas grown in the greenhouse in 1947 were found to exhibit considerably more tolerance than mustard to dilute sprays of 2,4–D. In the range of 1/4 pound per acre 2,4–D acid equivalent, peas were selectively weeded. Rather limited field tests indicated that pea yields were not adversely affected by 1/4 pound per acre of the triethanolamine salt of 2,4–D. The 2,4–D was applied in 1949 as a complete cover spray in 20 gallons of water per acre when the peas were breaking ground and up to 2 inches tall. Some curvature of the stem was visible within a day or two after spraying, but this deformity apparently did not affect the later development of the crop. Excellent control of mustard and other weed seedlings sensitive to 2,4–D was obtained, as is illustrated in Fig. 5. Where the tractor wheels crushed the pea plants after spraying with 2,4–D the plants recovered much slower. In this connection yield records in other experiments were not significantly different in the untreated plots between samples drawn from areas including the wheel tracks and from similar areas outside the tracks. Similar samples drawn from the sprayed plots indicated a tendency for higher yields outside the tractor tracks, but the differences did not approach significance at the 5 per cent level.

FIG. 5.—Excellent control of mustard with a spray of 1/4 pound of 2,4–D to the acre applied when the mustard was in the two true-leaf stage and the peas were 2 to 3 inches tall. (Photo by R. A. Wesselmann)

DISCUSSION

Selective weeding of a crop implies that the desirable crop plant persists in good condition after the undesirable weeds have been eliminated. Selectivity with a contact weed killer such as the dinitro compounds is only a relative matter. For instance, 6 pints of the ammonium dinitro ortho secondary butyl phenate burned off more pea leaves or caused more of them to flag and die when sprayed on an acre of ground with 25 gallons of water as a carrier than when applied with 75 gallons of water. However, the larger droplets from the 75-gallon rate may coalesce at the axils of the pea leaves and burn off the growing point, whereas with the 25-gallon rate this seldom occurs. Likewise, 6 pints of the dinitro spray applied at either dilution burns peas worse at an air temperature of 80° F than at 50° F. Overlapping of the spray boom usually results in damage to the peas, but the overlapping can be largely avoided by traversing the field in such a manner as to avoid making the return trip against freshly sprayed peas. The few minutes that it takes to make the return trip in another area of the field is frequently long enough so that the borders of the strip first sprayed can be distinguished from the unsprayed area.

Crop plants as well as weeds were more susceptible to damage from weed killers when they had grown rapidly and were succulent. The amount of weed killer must be varied then to compensate for the different environmental conditions that have influenced plant growth. Timeliness in making the application was very important because small weeds were killed more easily than when they had become large and well established. In order to utilize the killing power of cyanamid dust most effectively it should be applied when the weed foliage is heavy with dew and while the weeds are very small. The toxic properties of cyanamid are liberated into the water droplets on the margins of the leaves and thence absorbed by the leaves. If the dust is applied to dry foliage, it may be blown off before moisture gathers to activate the chemical.

Sodium chloride or sodium nitrate seem to be most effective when the evaporation rate is slow enough to permit absorption of the spray through the leaf before the salt is deposited as crystals on the surface of the leaf.

Although a great deal more evidence should be gathered on the use of 2,4–D as a weed killer for peas, the tests thus far are favorable and also illustrate further how relative the selectivity of a weed killer can be. The capacity of the pea plant to tolerate a chemical spray of 2,4–D may be largely a matter of its massiveness as compared to the slender weed seedling that succumbs as a result of the ¼ pound per acre 2,4–D spray.

Pea varieties may vary slightly in their response to weed killers as a result of leaf arrangement or the amount of cutin or waxy coating on the leaves. Pride, Canner King, Surprise, and Thomas Laxton were not materially different in the amount of injury sustained from the various treatments.

WEED CONTROL IN SWEET CORN

As early as 1942, Slade, Templeman, and Sexton (12) recognized that grasses would tolerate concentrations of plant-growth-regulating chemicals that were extremely toxic to broadleaved plants. Shafer, *et al.* (11) sprayed sweet corn in 1946 with 2,4–D and killed several species of troublesome broadleaved weeds growing in the corn field. Our knowledge of weed control in sweet corn has progressed rapidly and to a point where it is generally agreed that sweet corn can be weeded with 2,4–D.

The studies at Geneva have been primarily concerned with the use of 2,4–D at emergence of the corn or stages in its growth thereafter rather than at corn planting time. From this approach 2,4–D will be neither condemned for poor germination of the corn nor wasted in case the stand of corn is too poor to be retained for a crop. Furthermore, the per acre cost of material is at least 50 per cent less than when the material is applied immediately following planting.

The purpose of this study was to determine the following points:

1, At what stage of growth of sweet corn could a 2,4–D spray be used most effectively to weed the corn

2, What amount of 2,4–D acid equivalent should be used to the acre to kill the weeds without adversely affecting the yield of corn

3, If cultivation was necessary in conjunction with spraying for the control of weeds in corn

4, If the same acid equivalents of different formulations of 2,4–D were equally effective in controlling weeds in sweet corn

EXPERIMENTS IN 1947

In 1947 a study (5) was made to determine the effects of three concentrations of 2,4–D on the growth of sweet corn when applied at 11 different stages of growth of the crop. A fairly uniform stand of Golden Cross Bantam corn growing on Ontario silt loam soil was divided into 12 blocks. Each block constituted an experiment of 12 plots each 12 feet wide by 16 feet long. Each plot contained three record rows 3 feet apart, with a guard row on either side of the plot.

Four treatments were replicated three times on each of the 12 blocks. The treatments for 11 of the blocks were as follows: 0.0, 0.4, 0.6, and 0.8 pound of 2,4–D acid to the acre. The treatments for the other block were as follows: 0.0, 2.0, 3.0, and 4.0 pounds of 2,4–D acid to the acre. The triethanolamine salt of 2,4–D was used as a spray over the crop and weeds. A boom of three fan nozzles, operated by hand at 75 to 80 pounds pressure, was used to deliver the 2,4–D.

On July 1, 5 days after planting, block 1 received the fraction of a pound series of treatments and block 2 received the heavy 2,4–D treatments of 2.0, 3.0, and 4.0 pounds to the acre of 2,4–D acid equivalent. Approximately 30 per cent of the corn stand was showing above ground at this time. The remaining 10 blocks received the fraction of a pound of 2,4–D series of treatments as follows: July 3, block 3; July 8, block 4; July 14, block 5; July 21, block 6; July 29, blocks 7 and 8; August 1, block 9; August 6, block 10; August 14, block 11; and August 20, block 12.

Brace roots were beginning to develop on July 29. It seemed desirable to have a test of exposed versus covered roots in case lodging became serious later in the growth of the plants. Therefore, block 8 was treated before cultivation and block 9 after cultivation. Broadleaved weeds were pulled during the first week in August in the check plots of all blocks. It is recognized that this is not a true comparison of cultivation with chemical weed control because cultivation would take out the grasses as well as the broadleaved weeds.

The yield in tons per acre of ears in the husk varied markedly between experiments as can be seen from the data presented in Table 5. It is believed that the variable productivity by dates is due to location since experiments III, IV, VII, X, and XII fell on very poorly drained areas and experiments VIII, IX, and XI had good drainage.

Yield differences between treatments were statistically significant only in experiments V and VI. In these two cases the 2,4–D was applied 14 and 21 days after the corn broke ground. Both the 0.4 and 0.6 pound treatments resulted in an increase over the check of approximately 1 ton to the acre of corn. Corn plants that received 2,4–D in these two experiments showed a marked rolling of the leaves, as shown in Fig. 6, that persisted throughout the life of the plants. The only condition known to be peculiar to this date of application was that it was preceded by cloudy, showery weather for 3 days with a 0.15-inch shower on July 22. Corn seedlings in experiment II showed a similar rolling of the blades, but they outgrew the deformity in 4 to 5 weeks.

As a result of this study it seemed clear that these fractional rates of 2,4–D could be used to control the broadleaved weeds in sweet corn. Grasses gave the corn serious competition where cultivation was not practiced. Some lodging occurred throughout the field, but

TABLE 5.—YIELD OF SWEET CORN EARS IN TONS TO THE ACRE WITH VARIOUS 2,4-D TREATMENTS, 1947.

2,4-D, LBS. PER ACRE	EXP. I, JULY 1	EXP. II, JULY 1	EXP. III, JULY 3	EXP. IV, JULY 8	EXP. V, JULY 14	EXP. VI, JULY 21	EXP. VII, JULY 29	EXP. VIII, JULY 29	EXP. IX, AUG. 1	EXP. X, AUG. 6	EXP. XI, AUG. 14	EXP. XIII, AUG. 20
0.0	3.17	3.97*	1.57	0.68	2.16	2.33	2.13	4.75	4.25	1.19	4.43	2.36
0.4	3.46	2.96*	1.60	1.37	3.18	3.36	2.43	4.95	4.52	0.79	3.17	1.53
0.6	2.90	3.18*	1.87	1.32	3.07	3.39	1.61	3.61	4.91	0.73	3.46	1.09
0.8	2.86	2.52*	2.41	1.04	2.82	3.47	1.65	5.44	4.26	0.56	4.07	1.92
L.S.D. 5 per cent level	N.S.†	N.S.	N.S.	N.S.	0.56	0.63	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Yields for 0.0, 2.0, 3.0, and 4.0 pounds 2,4–D acid treatments, respectively.
†N.S. means differences are not significant.

FIG. 6.—Rolling of the leaf blades of sweet corn in response to excessively heavy concentrations of 2,4–D sprays.

the records indicated that it was not associated with treatment. Similarly, there were no significant differences in number of plants lodged in connection with the before cultivation treatment of block 8 versus application after cultivation in block 9.

The initial kill of broadleaved weeds was practically the same for each of the light rates of 2,4–D. Commercial control was affected with all applications against the following susceptible weeds: Lamb's quarters, ragweed, red-root. Wild lettuce, *Lactuca canidensis,* was slow in responding to these light rates and generally was not killed. Alfalfa that was not completely turned under in plowing was damaged but was not killed by these treatments. A few broadleaved weeds occurred as a secondary infestation in block I about 6 weeks after the plots were treated. It should be emphasized that there was an abundance of yellow foxtail, *Setaria glauca,* a scattered stand of smartweed, *Polygonum* sp., barnyard grass, *Echenochloa* sp., and quack grass, *Agrophyron ripens.* With the exception of quack grass this later infestation of weeds appeared to be somewhat delayed in emergence as a result of the weedicide applied. The only weeds that withstood the heavy 2,4–D treatment in block 2 were foxtail, smartweed, quack grass, and wild lettuce.

EXPERIMENTS IN 1948

In 1948 a study was conducted to ascertain if the productivity of Golden Cross Bantam sweet corn weeded with 2,4–D but not cultivated would equal or exceed the yield of sweet corn sprayed and cultivated or cultivated and hoed.

Four experiments were conducted in cooperation with two sweet corn growers. Experiments I and II were located in the same field but on very different soils. A dry, gravelly knoll was chosen for the site of the first experiment while a moist flat silty area of Ontario soil was selected for the second experiment. In each of these two experiments there were six replicates of three treatments. The treatments were as follows:

1, Sweet corn sprayed with 0.5 pound of 2,4–D and cultivated

2, Sweet corn sprayed with 0.5 pound of 2,4–D and never cultivated

3, Sweet corn cultivated and hoed

The average number of ears and the yield in tons per acre of husked sweet corn is presented in Table 6. The sample consisted of the ears from two 30-foot rows from each plot in experiments I and II and from two 50-foot rows from each plot in experiments III and IV. The significantly lower yield of corn produced on the 2,4–D sprayed and uncultivated plots (treatment 2) is attributed to the failure of this cultural practice to prevent grasses from competing with the corn for moisture and nutrients. Annual grasses, such as those shown on either side of the sprayed and cultivated area (center) in Fig. 7, illustrate how grasses thrive at the expense of the corn. This occurred after the broadleaved weeds were controlled with a post emergence spray of 0.5 pound of 2,4–D per acre. The only difference between the four rows of vigorous-appearing corn in the center of the picture and the adjoining grassy corn is that the grass was controlled by two cultivations in the center four rows.

TABLE 6.—EFFECT OF THREE METHODS OF WEEDING SWEET CORN ON THE NUMBER AND WEIGHT OF EARS OF MARKETABLE HUSKED CORN PRODUCED PER ACRE, 1948.

TREATMENTS	EXPERIMENT I		EXPERIMENT II	
	No. ears per acre	Tons per acre	No. ears per acre	Tons per acre
1, 0.5 lb. 2,4-D and cultivation	8,600	1.5	13,000	2.7
2, 0.5 lb. 2,4-D	3,700	0.2	11,100	2.2
3, Cultivated and hoed	8,800	1.6	11,900	2.6
L.S.D. 5 per cent level	2,800	0.4	1,600	0.3

Experiments III and IV were located on what appeared to be a uniform Ontario loam soil. Four treatments, 0.0, 0.5, 0.7, and 1.0 pound per acre of 2,4–D acid equivalent, were replicated four times in each experiment. In all experiments, when the sweet corn was about 4 inches tall, the treated plots were sprayed with 20 gallons per acre of water containing the proper amount of triethanolamine salt of 2,4–D to supply the desired acid equivalent of 2,4–D. Only one spray was applied and this was delivered at 30 to 35 pounds pressure to cover the entire area of a four-row plot. Experiments I and II were cultivated twice, while experiment III was cultivated three times. The check plots, cultivated three times, were the only areas cultivated in experiment IV. Weeds that remained in the check plots in experiments III and IV after cultivation were hoed out or pulled by hand.

In experiments III and IV grasses were not abundant and consequently the corn in the sprayed plots was practically free of weeds. Some bending of the young corn plants occurred following the 1.0-pound application of 2,4–D, but these plants recovered. At harvest time there were no visible differences among the plants in the several treatments. The yield data for these two experiments are summarized in Table 7. Since all plots in experiment III were culti-

Fig. 7.—Golden Cross Bantam sweet corn in the center four rows weeded with 0.5 pound 2,4–D to the acre plus two cultivations versus four rows on either side that were weeded with the same 2,4–D spray but never cultivated to control the grass.

vated and hoed, any significant differences between treatment yields is presumed to be due to the weed control practice or to soil heterogeneity. A significant increase in number of ears and tonnage resulted from the 1.0-pound treatment over that of the check. If this increase is due to treatment, it indicates that 2,4–D has increased the capacity of the plant to produce more marketable ears. Inasmuch as the increase in tonnage is not directly proportional to the increase in number of ears, it is evident that the ear size decreased as the number of ears increased.

In experiment IV where only the check plots were cultivated, the yield of ears per acre did not differ significantly among the four treatments. However, the tonnage of corn on the 1.0-pound treatment was less than either the check or the 0.5-pound treatment when compared at the 5 per cent level of significance. Soil heterogeneity may have been responsible for this condition. It is interesting to note that the average weight per ear in pounds decreased as the rate of 2,4–D increased. Since this is consistent for experiments III and IV, it seems likely that the significant variation in number of ears produced on the 1.0-pound 2,4–D spray in experiment III may not be a result of treatment. In viewing the results of the two experiments it will be seen that the tonnage of corn produced on the 1.0-pound 2,4–D treatment that was not cultivated (Table 7, column 6) is not only lower than the yield of the cultivated check but also lower than the yield of the 1.0-pound treatment that was cultivated in experiment III. In this connection both the writer and other re-

TABLE 7.—EFFECT OF POST EMERGENCE SPRAYS OF 2,4-D AND OF CULTIVATION ON THE YIELD OF GOLDEN CROSS BANTAM SWEET CORN, 1948.

2,4-D TREATMENTS, LBS. PER ACRE	EXPERIMENT III, ALL PLOTS CULTIVATED AND HOED			EXPERIMENT IV, ONLY CHECKS CULTIVATED AND HOED		
	No. ears per acre	Tons per acre	Av. weight per ear, lbs.	No. ears per acre	Tons per acre	Av. weight per ear, lbs.
0.0	9,300	2.8	0.60	10,500	3.1	0.59
0.5	9,200	2.7	0.58	10,500	3.1	0.59
0.7	9,300	2.6	0.56	10,300	3.0	0.58
1.0	11,300	3.1	0.54	9,800	2.6	0.53
L.S.D. 5 per cent level	900	0.2		N.S.*	0.5	

*N.S. means differences are not significant.

search workers in the State observed a commercial field of sweet corn in which one half of the field had been cultivated several days after a uniform post emergence spray of 2,4–D had been applied. In the cultivated area the corn plants, including some near the tassel stage of development, appeared normal while the leaves of similar corn plants on the uncultivated portion of the field were badly rolled. This rolling of the corn leaves in the absence of cultivation is illustrated in Fig. 8.

FIG. 8.—Sweet corn showing rolling of the leaf blades where the crop was sprayed and not cultivated (right) versus normal growth where cultivation followed spraying with 2,4–D. (Courtesy Vegetable Crops Department, Ithaca, N.Y.)

Too frequently growers overlook the seriousness of the weed population in their sweet corn. This condition is generally recognized when the corn is 18 to 24 inches tall and when the weeds are beginning to protrude above the corn. The results of the 1948 experiments indicated that broadleaved weed control could be affected in sweet corn with 0.8 pound of 2,4–D per acre applied at a rather late stage of maturity of the corn plant.

EXPERIMENTS IN 1949

It seemed desirable to determine if at a late stage of development of the corn plant, the 2,4–D spray should be applied (a) above the corn foliage, (b) below the corn foliage, (c) ahead of the cultivator at the last cultivation, or (d) to the rear of the cultivator at the last cultivation. It also seemed worthwhile to include different formulations of 2,4–D for the purpose of comparing their weed-killing capacity and their differential effects, if any, on the corn plant.

The site for the 1949 study was 112 × 500 feet located on well-fertilized Ontario silt loam soil of a 6-acre field of Golden Cross Bantam sweet corn. On June 6 the corn was planted with a four-row planter 28 inches between rows. The corn was cultivated June 20 and July 11 only. In conjunction with the last cultivation, at which time the corn was 2 feet tall, four formulations of 2,4–D were applied separately on plots four rows wide and 100 feet long. All sprays were applied from a tractor equipped to spray and cultivate two rows at a time. A boom was mounted in front and one on the rear of the tractor in order that sprays might fall on the soil and be cultivated in or fall on the soil and remain undisturbed for the remainder of the season. There were three drop pipes and four fan nozzles per boom. Both were attached to the tractor so that the drop pipes could be rotated up and down to permit spraying above the crop or below the corn foliage. All sprays contained the equivalent of ¾ pound of 2,4–D acid in 13.7 gallons of water. They were applied at this rate per acre and at 35 pounds pressure.

The chemicals used were two formulations of the triethanolamine salt, isopropyl ester, and ethyl ester of 2,4–D. The test for a given chemical involved cultivation, the application of a spray in front of the tractor above the corn, in front and below the corn foliage, to the rear above the corn, and to the rear below the corn foliage. Chemicals, positions of sprays, check plots, and replicates were well randomized. There were 60 plots embracing three replicates of four chemicals applied in four positions plus the cultivated nonsprayed checks.

Notes on the response of the corn and weeds were recorded. Yields of unhusked corn and number of ears per plot were recorded at the prime canning stage of the sweet corn from two 50-foot sections of the two center rows in each plot. It seems well to point out that 0.36 inch of rain fell one week after spraying, 1.20 inches two weeks after, and 0.30 inch on July 31, or 20 days after the sprays were applied. In August there were two showers totaling 0.73 inch of rainfall. Considering the fact that the months of May and June were very dry, it is evident that the soil moisture was below normal for this area.

The data in Table 8 show that neither the chemical used in weeding nor the position from which it was sprayed produced any significant difference in the yield of sweet corn. This is in agreement with the 1947 results (5) in that 0.6 and 0.8 pound of 2,4–D sprayed

TABLE 8.—EFFECT ON YIELD OF SWEET CORN OF FOUR FORMULATIONS OF 2,4-D IN 1949.*

Treatment	Spray nozzles				Yield, tons per acre	
	Front		Rear			
	Above†	Below	Above	Below	Average for treatments	Check
Amine salt.....	2.8‡	2.9	2.3	3.0	2.7	2.7
Amine salt.....	2.9	3.1	2.9	2.9	2.9	2.7
Isopropyl ester.	2.9	2.7	2.7	2.9	2.8	2.4
Ethyl ester.....	3.0	2.4	2.8	2.8	2.5	2.6
Average.......	2.9	2.8	2.7	2.9	—	2.6

*Differences not statistically significant at 5 per cent level.
†Above corn and weed foliage.
‡Each figure is average of three replicates.

over sweet corn at a late stage of growth did not affect the yield of corn. Thus, with regard to Golden Bantam sweet corn, it seems safe and practical to use a complete cover spray of 3/4 pound of 2,4–D on weedy corn that has developed to an average height of 2 feet. Since the yield of corn was not affected by the treatments, any differences in weed control due to the method of application becomes highly significant. In this respect it was noted that the sprays applied above the corn either in front or in the rear of the tractor gave a complete kill of those weeds sensitive to 2,4–D even though they stood as high as the corn. In contrast, where the sprays were applied below the corn or 8 to 12 inches above the ground, only the lateral branches of lamb's quarters, red-root, and ragweed were killed. The ester killed a higher proportion of the lateral branches but did not as a rule kill the terminal growing point when applied below that region of the plant. Rolling of the corn leaves occurred only where the esters were used. However, the response was not extensive or serious.

The ¾ pound of 2,4–D sprayed forward of the tractor and mixed into the soil with the cultivator failed to prevent the germination and growth of weed seeds that were turned up by the cultivator. At this late stage of corn development these weeds were not important, yet the test demonstrated that a more lasting job of weeding was obtained from the 2,4–D used following cultivation.

DISCUSSION

Weeds generally troublesome in sweet corn are mustard, lamb's quarters, red-root, ragweed, and smartweed plus quack grass and annual grasses. The weeds that are predominant on a particular farm are frequently the result of previous cropping practices. Many weeds in sweet corn can be destroyed through the proper use of the cultivator. However, the weeds within the corn row are not only difficult to cover with the tillage tool, but are the particular ones that compete with the corn for water and nutrients. A complete cover spray of ¾ pound of 2,4–D per acre applied when the corn is breaking ground or within a week thereafter kills the broadleaved weed seedlings between the rows as well as within the rows. Thus, early cultivation to control these weeds is not necessary.

With this practice, annual grasses, if present, may germinate and grow rapidly because the killing of the broadleaved weeds with 2,4–D will have removed the usual shade. Grasses are readily controlled through proper cultivation after the corn has attained enough height so that the soil can be thrown against the corn with the cultivator. The amount of 2,4–D to be used as a post emergence spray is highly important and should be controlled within the range of 0.5 pound to 0.8 pound to the acre. Sprays containing less than 0.5 pound of 2,4–D acid equivalent to the acre fail to control large weeds, while sprays carrying more than 0.8 pound of 2,4–D may cause excessive rolling of the corn foliage. The volatile esters of 2,4–D may be dangerous for the vegetable grower even though sweet corn can be weeded easily with them. The vapors that arise from fields sprayed with ester forms of 2,4–D may drift in the air currents to sensitive crops. It should be emphasized that 2,4–D is a potent weed killer and careless use of even the amine forms may result in heavy damage to vegetable crops, fruit trees, and ornamental plants.

WEED CONTROL IN BEETS

Screening tests of chemicals conducted in the greenhouse in 1947 indicated that sodium chloride or sodium chloride plus sodium nitrate gave good control of mustard, ragweed, red-root, and smartweed. In a preliminary report, Warren (16) showed that beets tolerated highly concentrated sprays of several salts, including sodium chloride and sodium nitrate. Troublesome weeds that were not injured were lamb's quarters and purslane, *Portulaca oleracea.*

In a mixed planting of lamb's quarters and beets in the greenhouse at Geneva azobenzene scorched the weed quite badly without affecting the beet foliage, but studies with azobenzene have been limited because of the toxic nature of the compound to humans.

In producing beets for canning, growers plant the seed thick in order to get a good tonnage of small beets. Canners prefer small beets (¾ to 3 inches in diameter) and pay a higher price per ton for them than for larger sizes. Therefore, any treatment which directly or indirectly kills some of the beet plants in a desirable stand, decreases the cash value of the crop even though the lower stand might produce the same total tonnage of beets per acre.

The purpose of this study was to determine (a) if beets can be weeded satisfactorily with sodium chloride or a mixture of sodium chloride and sodium nitrate, (b) if the stand or yield of beets is affected by the weeding practice, and (c) if the sodium chloride supplied as a spray could be expected to increase the yield of beets to the same extent as is obtained where the beet fields are fertilized with 400 or 500 pounds of sodium chloride (10) at seeding or several days before seeding.

EXPERIMENTS IN 1947

The studies in 1947 were confined to extremely weedy beet fields that were to have been abandoned by the grower because the cost of hand weeding was prohibitive. Four 1-acre strips of Detroit Dark Red beets were sprayed with a tractor-drawn power sprayer. Two hundred gallons of water containing 400 pounds of fine granulated salt were applied to the acre. In addition, a similar area was sprayed with the same volume of water containing 320 pounds of sodium chloride and 240 pounds of sodium nitrate. This ratio of chemicals was chosen because the combination dissolved faster than the 400 pounds of sodium chloride. Two fan-type spray nozzles per row were used to concentrate the sprays on an 8-inch band which included the beet row. These sprays killed 60 to 70 per cent of the stand of weeds which were predominantly mustard, ragweed, and red-root. The results were so encouraging that the entire 10-acre beet field that had been abandoned was recovered after spraying and hand weeding. Yield records for the individual strips were not obtained; however, the yield for the 10 acres was over 12 tons per acre which was above average in the area.

EXPERIMENTS IN 1948

The study in 1948 was conducted in cooperation with four beet growers. The experimental sites were selected in what appeared to be uniform stands of canning type beets growing on well-fertilized Ontario silt loam soil. Rock salt at the rate of 400 to 500 pounds to the acre was drilled in as a soil amendment the day the beets were seeded. The beet seeds were drilled in rows 24 inches apart. All plots were four rows wide by 30 feet long, alternated with check plots in a systematic design. On locations 1 and 2 there were eight replicates of two sprays with their check. At locations 3 and 4 there was a sodium chloride spray and a check treatment replicated six times.

The spray treatments were composed as follows:

1, 400 pounds of sodium chloride dissolved in 200 gallons of water

2, 320 pounds of sodium chloride and 240 pounds of sodium nitrate dissolved in 200 gallons of water

Treatments 1 and 2 were applied at 50 pounds pressure at location 1 and at 100 pounds pressure at location 2. The sodium chloride spray was applied at location 3 at 50 pounds pressure and at location 4 at 100 pounds pressure. The mixture of salts was not used at sites 3 and 4.

Since it was only the weeds within the beet rows that could not be removed by cultivation, the sprays were concentrated on the rows with two flat fan-type nozzles. The boom carried four pairs of nozzles arranged over four rows and set at diagonals with their respective rows to cover a band 8 inches wide.

On this basis 200 gallons of spray solution would cover the beet rows in a 3-acre block because only one third of the area of land drilled to beets 24 inches between rows was actually in the path of the spray. All sprays were applied when the beets were in the three to 5 true-leaf stage of growth. In all experiments the growers cultivated all beets and in addition hand-weeded the unsprayed plots.

When the crop was mature the beets in the two center rows of each plot, less a foot on either end of the rows for border effect, were pulled and topped with the mechanical roll-topper. Records were taken of the total number and total weight of beets topped from each plot. A weed count was made 16 days after spraying at location 1. Beets from unsprayed, sodium chloride sprayed, and sodium chloride plus sodium nitrate sprayed plots were prepared from each treatment, diced, packed in a salt brine, sealed in tin and processed in accordance with commercial practice.[4]

The foliage of beets and the foliage of mustard, ragweed, redroot, and smartweed became flaccid within 20 minutes after spraying with either the sodium chloride or the sodium chloride plus sodium nitrate mixture.

The beets recovered their turgidity within a few hours, although the margins of some leaves developed irregularly as a result of the spray burn. Water-soaked areas appeared in the beet leaves shortly after spraying with pressures of 100 pounds or greater. As the beet crop matured the foliage of the beets on the plots receiving the sodium chloride plus sodium nitrate remained erect and greener than did beets growing on either the sodium chloride or the check plots.

The average stand of beets as measured by the number which developed to marketable size, that is ¾ inch or over, and the average yield in tons per acre are presented in Table 9 for the four locations.

Within a given location the small differences between the means for the unsprayed and the sprayed plots are not statistically significant. This statistical interpretation is based on the assumption that the systematic design did not introduce an unusual bias. The fact that the stand and yield for the sprayed and unsprayed beets were similar at the four locations and at two different pressures of spray application indicates that the crop was not adversely affected by the sodium chloride spray. Although the sodium chloride plus sodium nitrate spray mixture was only tested at locations 1 and 2, the data indicate that the beets responded the same as they did with the sodium chloride spray. There was no evidence of in-

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[4]Assistance on this phase of the work from the Division of Food Science and Technology at this Station is gratefully acknowledged.

TABLE 9.—EFFECT OF SALT SPRAYS AT 50 AND 100 POUNDS PRESSURE ON FINAL STAND AND YIELD OF BEETS, 1948.

TREATMENT, 200 GALLONS PER ACRE	LOCATION 1, 50 LBS. PRESSURE		LOCATION 2, 100 LBS. PRESSURE		LOCATION 3, 50 LBS. PRESSURE		LOCATION 4, 100 LBS. PRESSURE	
	Count*	Tons per acre	Count*	Tons per acre	Count†	Tons per acre	Count†	Tons per acre
Not sprayed........	3.5	11.8	4.4	18.8	7.5	15.2	3.9	11.4
NaCl (400 lbs.)......	3.3	12.0	4.6	20.0	7.3	15.2	4.0	13.3
Not sprayed.........	3.5	10.2	4.6	20.5	—	—	—	—
NaCl (320 lbs.) plus $NaNO_3$ (240 lbs.)..	3.5	11.5	4.1	20.2	—	—	—	—

*Average stand of beets per foot of row from eight plots at harvest.
†Average stand of beets per foot of row from six plots at harvest.

creased tonnage as a result of the 12.8 pounds of nitrogen added per acre through the sodium nitrate in the spray. Even though the actual tonnage was not increased by the nitrate in the salt plus nitrate mixture, it appeared on strips sprayed with this mixture that the mechanical harvester picked up a higher percentage of the beets because of the erectness of the tops. Since the beet yields were not adversely affected by the sprays, any material reduction in the weed population should be highly important.

The average weed count for eight plots of each of two spray treatments and their respective checks, together with the least difference necessary for significance, is presented in Table 10.

The high weed count on the unsprayed plots represents a stand of ragweed, red-root, mustard, and smartweed within the 8-inch row that was typical of the beet field. Obviously it was not neces-

TABLE 10.—EFFECT OF SODIUM CHLORIDE AND SODIUM CHLORIDE PLUS SODIUM NITRATE SPRAYS ON THE CONTROL OF WEEDS OTHER THAN LAMB'S QUARTERS AND PURSLANE IN BEETS, 1948.

TREATMENT	LOCATION I, WEED COUNT PER ACRE BEFORE HAND WEEDING
Not sprayed..	10,900
Salt sprayed, 200 gals. at 50 lbs. pressure...............	400
Not sprayed..	10,300
Salt plus sodium nitrate sprayed, 200 gals at 50 lbs. pressure..	200
L.S.D. at 5 per cent level............................	3,300

sary to hand-weed the sprayed plots. Even when hand weeding must be practiced in conjunction with spraying to control lamb's quarters, the problem is greatly simplified by the removal of the salt-sensitive weeds, as is indicated by the salt-sprayed center row in Fig. 9. In addition, weeds sprayed with salt die rapidly; whereas, many weeds that are pulled and dropped between the beet rows soon become re-established and produce seed.

FIG. 9.—Beets and weeds in the center row were sprayed with a salt solution at the rate of 200 gallons per acre of area actually covered.

Beet samples which had been canned and held in tin for about 7 weeks were rated by a panel of food-tasting experts at the Station. In no instance, was there a difference between the unsprayed and sprayed samples that could be attributed to the spraying with sodium chloride or sodium chloride plus sodium nitrate.

Chemical weeding adds another operation in the culture of beets that involves farm labor and machinery in contrast to hand weeding, where the grower may hire the work done through the manager of a large hand-weeding labor force. Inasmuch as salt is already being drilled into the soil before planting, it seemed desirable to learn if the salt spray used in weeding beets would supply enough salt for the requirements of the beet crop. If this requirement could be met through the weeding process with a salt spray, a grower would not have the rapid rate of depreciation on an expensive grain drill as a result of salt corrosion.

EXPERIMENTS IN 1949

In 1949 an experiment was conducted to test the effectiveness of sprays of sodium chloride and sodium chloride plus sodium nitrate as herbicidal treatments for beets. The field plan laid out in a 6 × 6 latin square design made it possible to gain information as to whether or not the salt spray would obviate the present practice of drilling salt into the soil before planting. All plots were four rows wide by 30 feet long.

The treatments used per acre were as follows:

1, Salt 500 pounds drilled in before planting

2, Salt 500 pounds drilled in before planting plus 133 pounds as a post emergence spray

3, Salt 500 pounds drilled in before planting plus 106.6 pounds of sodium chloride and 80 pounds of sodium nitrate as a post-emergence spray

4, Salt 133 pounds as a post-emergence spray only

5, Salt 106.6 pounds plus sodium nitrate 80 pounds as a post-emergence spray only

6, No salt or sodium nitrate either from the drill or the sprayer

The average yields of marketable topped beets in tons per acre are presented in Table 11, together with their respective treatments.

It should be realized that these results were obtained from only one experiment conducted during the very dry season of 1949. The data indicate that the amount of salt or salt and sodium nitrate that was supplied the beet crop through the spray was less than that

TABLE 11.—YIELD OF TOPPED BEETS FROM SPRAYED AND NONSPRAYED PLOTS, 1949.

Treatment	Pounds per acre applied: Drilled, Rock salt	Pounds per acre applied: Sprayed, Sodium chloride	Pounds per acre applied: Sprayed, Sodium nitrate	Yield per acre: Tons of beets	Yield per acre: Number of beets
1, Salt only	500	0	0	5.3	78,120
2, Salt only	500	133	0	5.9	89,430
3, Salt plus sodium nitrate	500	106.6	80	5.9	87,580
4, Salt only	0	133	0	4.5	73,960
5, Salt plus sodium nitrate	0	106.6	80	3.9	76,230
6, None	0	0	0	4.1	79,540
L.S.D. at 5 per cent level				1.0	N.S.*

*N.S. means differences are not significant.

necessary for good yields. If the yield of the check plot is compared with the yield of any sprayed plot, it will be noted that the sprays did not result in a reduction of stand or yield of beets.

DISCUSSION

Although the control of weeds in beets with concentrated sprays of sodium chloride or sodium chloride and sodium nitrate was not as complete as the control of the same weed species in other crops with other chemicals, the salt sprays did control a high percentage of the weeds.

Contrasting the spray treatment with hand weeding, it should be noted that the beets were sprayed and much of the weed competition eliminated at least a week earlier than it would be practical to pull the weeds by hand. Furthermore, the spray killed many small weed seedlings that in the hand-weeding operation would be overlooked. Even the seedling grasses were killed at an early stage of growth, that is, while they were still only an inch tall. Beets in the cotyledon stage and up through the two true-leaf stage of growth were also killed or severely damaged by these sprays. Thus, one must delay the spraying of beets until the desired stand has emerged and grown through the two-leaf stage.

In a very dry season when a seeding germinates irregularly, it may be found advantageous to spray the beets and weeds twice, the first spray being applied when the beets of the first emergence have grown the necessary foliage.

Considering salt versus salt plus sodium nitrate as a selective weed killer for beets, it would seem that for the producer of beets for processing the salt spray is the more economical. The mixture containing nitrate of soda did not result in increased yields; however, the beets in these experiments were harvested late in the season and any differences in size that may have existed earlier may have been equalized at the late harvest date.

The corrosive nature of these sprays, together with the high volume of water necessary to dissolve the required amount of the sodium chloride or sodium nitrate, are distinct disadvantages in their use.

SPRAY EQUIPMENT

Some information regarding spray equipment and its use was gained through these studies that may be of practical value to the vegetable grower. A simple and relatively inexpensive tractor-mounted sprayer can be constructed to fit several standard makes of farm tractors. If there is a choice of tractors on which to mount the sprayer, select the one with wheels easily adjustable to different row widths. This is an especially important feature to have built into a trailer type of sprayer. For low-volume spraying, such as weed control in corn and small grains, the tractor-mounted unit is most desirable because of its compactness. Even with row crops where larger volumes of spray solutions are applied, it seems desirable to place all of the equipment on the tractor. In either case the spray boom carrying the nozzles for row crop work should be mounted on the tractor. Otherwise, it is difficult to center the spray pattern on the row. Spray booms mounted just in front of the rear wheels deliver a spray pattern on the row with less deflection when the tractor wheels hit a stone than the spray pattern from nozzles mounted on a boom either to the front or to the rear of the tractor. Bronze-gear pumps[5] driven through a V-belt or sleeve coupling from the power-take-off shaft of the tractor were found to be very satisfactory for pumping spray solutions.

From the standpoint of simplicity it seemed more desirable to attach a gear pump with ample capacity at a low r.p.m. to the power-take-off by means of a sleeve rather than to drive a smaller pump at a higher speed through the use of differential pulleys and belt as shown in Fig. 10. Belt slippage results in variable pressures and power loss.

A pressure regulator in the outlet line that permits the surplus spray material being pumped to be returned to the spray tank is desirable both for cooling the pump and keeping the solution mixed. Agitators are not generally built into the weed control sprayer, hence the value of the return solution.

Spray booms for use on row crops should conform to the planting system. If beet seeds are planted with a four-row planter, the nozzles on the boom should cover four rows at a time and the same four rows that were planted as a unit. Fig. 11 illustrates this point, together with one arrangement of nozzles for spraying beets.

Spray nozzle bodies designed for interchangeable tips are highly

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[5]The writer is extremely grateful to the following manufacturers who so generously provided pumps and accessories throughout the course of these studies: Kupfer Products, Inc., 1025–1041 East Wilson St., Madison 3, Wis.; Oberdorfer Foundries, Inc., Syracuse, N.Y.; and Tuthill Pump Co., 939 East 95th St., Chicago 19, Ill.

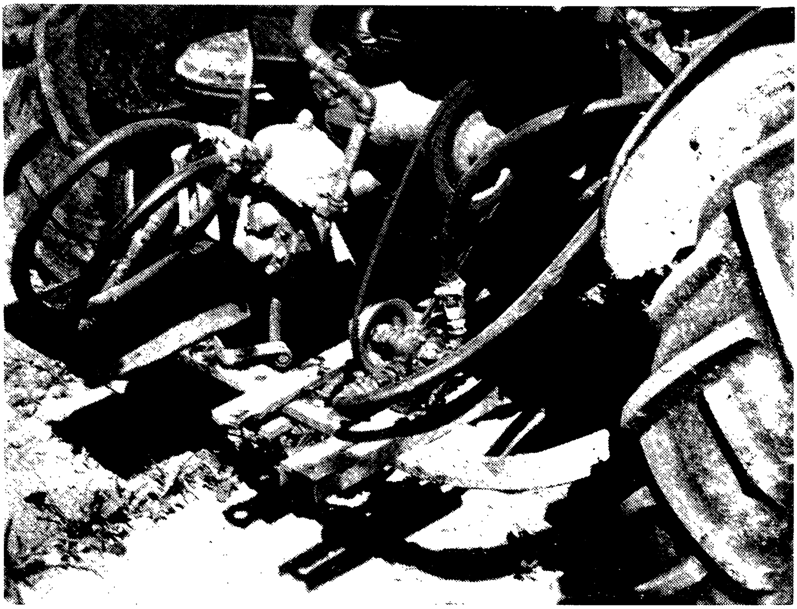

FIG. 10.—Large gear-pump driven directly from the power take-off-shaft (left) and smaller gear pump driven with V-belt (right). (Photo by R. A. Wesselmann)

FIG. 11.—Applying salt spray to weed beets. Rigid copper tube boom with two nozzles per row makes a simple type of construction. Operator is controlling valves that determine flow of solution to boom for spraying this experimental plot.

desirable since they add versatility to the sprayer with very little added investment. Nozzle strainers with built-in check valves to prevent the spray solution from dripping from the nozzles save a lot of spray solution. Concentrated sprays of 2,4–D may drip and kill desirable vegetation while the equipment is traveling from the supply shed to the field.

Equipment used for spraying 2,4–D frequently becomes contaminated on its surface to such an extent that sensitive crops, such as tomato, squash, and beans, are materially injured by merely brushing against the cultivator teeth or under parts of the tractor. A thorough rinsing of these parts with water from a hose will go a long way toward reducing this 2,4–D hazzard. Thorough rinsing is just as important after using salt sprays, but in this case it is done to protect the equipment from corrosion. Hooding the spray boom has aided materially in controlling spray drift and preventing contamination of the equipment.

SUMMARY

Wild mustard in canning peas decreases yield, increases the labor involved in mowing and handling peas, and increases the vining time per ton of shelled peas recovered. Selective weeding of peas was accomplished with a single spray applied when the peas were 4 to 8 inches tall. Water was used for the diluent for all sprays.

Chemicals that effectively controlled mustard in peas included sodium chloride, a mixture of sodium chloride and sodium nitrate, ammonium dinitro ortho secondary butyl phenate, and potassium cyanate. Finely powdered calcium cyanamid dispersed in dust form by airplane gave good control of mustard when weather conditions were favorable for its use. With either the dinitro compounds or cyanamid dust the peas showed the effects of the chemical burn for about a week. Potassium cyanate caused a distinct yellowing of the peas which was also considered as a spray burn. At the concentration of chemicals used in these studies, growers need not be alarmed about the wilting or discoloration of pea foliage. Weed-free peas recovered rapidly. Peas were seriously damaged only where the pattern of the spray boom overlapped areas that had been sprayed previously. Peas showed no burning where the sprays of sodium chloride and sodium nitrate were used. Likewise lamb's quarters was not injured by these two chemicals and could be a real problem following the use of these salt sprays.

2,4–D for weeding peas is still in the experimental stage but warrants further field testing.

Sweet corn has shown a rather high tolerance to a complete cover spray of 2,4–D. Conversely, broadleaved weeds common in sweet corn fields were killed by concentrations of 2,4–D that produced a visible effect only temporarily in the early growth of the sweet corn. Post-emergence sprays of 2,4–D used at concentrations within the safe range for Golden Cross Bantam sweet corn did not satisfactorily control annual grasses; therefore, cultivation was essential in fields where annual grasses were abundant.

The weeding of sweet corn was satisfactorily accomplished except for grasses with the equivalent of ¾ pound of 2,4–D acid to the acre applied when the corn was breaking ground or up until the corn was 6 to 8 inches tall. When it was impossible to spray corn during this period, the same rate of 2,4–D per acre was used with equal success in killing the weeds providing the spray nozzles were carried high enough to cover the terminal growth of the sensitive weeds. More visible crop response in the form of leaf rolling was observed with the later applications particularly where the ester forms of 2,4–D were used. Sprays of 2,4–D applied in conjunction with cultivation but following the stirring of the soil inhibited weed growth longer than the same concentration applied and mixed with the soil directly by the cultivator teeth. No evidence was gathered during the very dry season of 1949 to indicate that the growth of corn was modified more by 2,4–D where it had been applied to the soil and left undisturbed for the remainder of the season than where it was cultivated in directly after spraying.

Beets in the seedling stage present quite a different problem in weeding than do peas and sweet corn. The mass of the seedling beet is small as compared with seedling pea and corn plants. The leaf is broad and tends to funnel the spray materials toward the growing point. Beets were selectively weeded with sprays of sodium chloride and sodium chloride plus sodium nitrate; however, lamb's quarters and purslane remained uninjured. This was an undesirable situation which limited the use of these sprays.

The completeness with which sensitive weeds, including very young grasses, were killed by salt sprays applied at 20 to 50 pounds pressure has made it seem doubtful if higher pressures are necessary. Where spraying was delayed and the weeds were 8 to 10 inches tall, higher spray pressures gave better coverage of the small weeds that were normally shielded by the larger weeds. Stand and yield of beets was not affected by the salt sprays providing they were applied after the beets had developed two true leaves.

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