Weed-control Studies on Sugar Beets Using Pre-emergence Treatments

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Weed control in sugar beets, particularly in the beet rows, has become more and more of a problem as single-seed, precision-type, sugar beet planters have been developed together with the use of small-sized whole seed, segmented or other processed seed at lower and lower-seeding rates. The increased uniformity and precision of seed drop of these planters, the higher percentage of single-germ seed, and the low-seeding rates have resulted in seedling stands requiring less and less hoeing in the beet row to thin to a desired field stand. As a result, weeds have become more troublesome and part of the savings in thinning labor have been lost because of the need of more weed hoeing later. This was especially pointed out early by the Utah-Idaho Sugar Company. On some of their new-type plantings, the labor needed for weed control in the rows was as much as would have been required for thinning with old-style plantings. Weed control had become one of our chief concerns in sugar beet mechanization by the spring of 1946 and became one of our chief objectives for 1947.

A report in 1946 by L. W. Kephart, United States Department of Agriculture agronomist, on weed control on other crops than sugar beets by pre-emergence control methods, pointed out a promising solution to our weed problem in sugar beets. In his paper[2] he pointed out that few weed seeds would germinate until brought within 3/8 of an inch of the soil surface and only then when moisture and temperature conditions are right. He described methods of pre-emergence weed control, the most applicable being to fit the seedbed and allow the weed seeds to germinate and start, then destroy the weeds by spraying with a herbicide or burning. Planting of the crop is done either immediately before or after the weeds are killed using a planter which causes a minimum disturbance of the soil. Thus, no more weed seeds are brought up near the soil surface to germinate and grow that season.

The 1947 weed-control study on sugar beet plots of the sugar beet machinery project of the United States Department of Agriculture and the Colorado Agricultural Experiment Station at Fort Collins, Colorado, was based on Mr. Kephart's paper. These plots were put in by the Division of Farm Machinery with the cooperation of G. W. Deming of the Division of Sugar Plant Investigations, both of the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Mechanical Engineering, Weed

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[2]L. W. Kephart, "Weed control with chemicals," a paper prepared for presentation at the annual meeting of the American Society of Agricultural Engineers in June 1946 and published in the November 1946 Agricultural Engineering, Vol. 27, No. 11, pages 506-8.

Control Investigations and Agronomy Sections of the Colorado Experiment Station. The plots included six treatments replicated six times in a Latin square. Each plot was 4 beet rows wide by 130 feet long and contained 1/50 of an acre as the beet rows were on 20-inch centers. The treatments were as follows:

1. Pre-emergence control by burning of the weeds.
2. Pre-emergence control by spraying with a herbicide.
3. Control by shallow cultivation just before planting.
4. Control by shallow cultivation and spike-tooth harrowing just before planting.
5. Covered-row planting in the weedy seedbed.
6. Check (no weed-control work).

The plot ground was disked, irrigated, manured and fall-plowed. It was left in the rough during the winter until it was spike-tooth harrowed in February. Seedbed fitting was begun in late March when field work was being started in this section. The field needed considerable spring-toothing and floating to level, and wet weather and wet soil delayed completion of the seedbed until April 21. It was then allowed to lie so that the weeds could sprout and grow. The weed growth was sufficiently advanced by mid May for our planting and pre-emergence weed control, but wet weather delayed the planting until June 6. Figure 1 shows, under the planter, the stage of weed growth at the time planting was done. This was later than we had wanted to plant. We are carrying on this type of weed-control investigations this next season and we plan to get our seedbed fitted in the late fall or early winter, if possible. Our weed growth around Fort Collins usually starts late in April and we hope to do our planting by late April or early May. One objection to weed control by pre-emergence treatments, in areas where seed growth does not start until spring, is the delay in planting necessitated by waiting until weed growth has started.

Planting for all treatments was done with a No. 55 John Deere planter using the new No. 64 planter seed plates and cut-offs and special false plates with 5/8-inch diameter, smooth, slightly curved seed tubes. Double disk openers were used with depth bands set for 1 1/2-inch planting depth and with bevel-rim press wheels set in normal position about 3/4 of an inch apart. Small disks were mounted behind the press wheels for the covered-row planting, but were held up off the ground for all of the other plantings.

Segmented seed, 7/64- to 10/64-inch, was used at a seeding rate of 1.85 pounds per acre in 20-inch rows. The planter drives used gave 2.42 seed cells per foot of forward travel or 4.95 inches per cell. Planting speed was 2.35 miles per hour. As the planting was late, 45 pounds per acre of ammonium phosphate (11-48-0) was put in with the seed to start the growth faster.

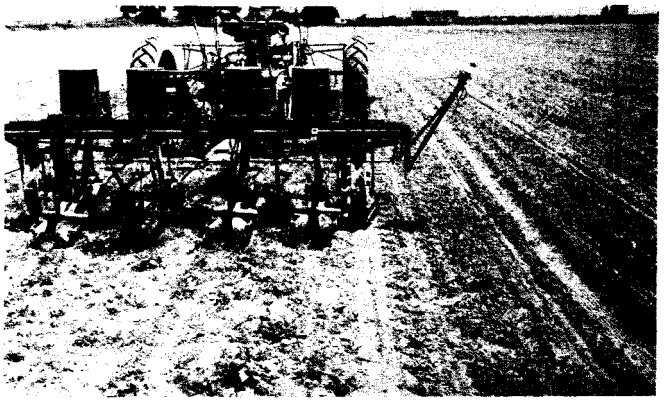

Figure 1.—The sugar beet plots for weed control by pre-emergence burning or spraying were planted right in the weed growth. The four-row plot to the right of the planter was shallow-cultivated just before planting. The small disks at the rear of each opener were used for the covered-row planting, but were lifted as shown for the regular planting.

Planting for treatment No. 1, pre-emergence burning to kill the weed growth was done directly in the weed growth as shown in Figure 1. Burning of the weeds was done with a New Holland, model PNH1-4A, 4-row Sizz-Weeder mounted on a Farmall H tractor as shown in Figure 2. This burner was supplied by the New Holland Machine Company, New Holland, Pennsylvania, for this work and they sent David M. L. Forbes of their company to help us with the adjustment and operation of the machine. The eight burners were set in line in a vertical position on 10-inch centers with their lower ends about 5 inches above the ground so as to cover completely with flame the 4-row beet plot. However, we found later that we got a slightly better weed kill, perhaps, by lifting the burners about 1 foot off of the ground, using the hydraulic lift on the tractor to hold the burners in the desired position. Other positions or burner angles probably might give even more effective weed kill.

The fuel used in the burner was propone and the pressure regulator was set to give 35 pounds per square inch of gas pressure on the burners. The burner is designed for use of either commercial propane or butane. Preliminary tests at tractor speeds ranging from 1.13 to 3.34 miles per hour gave increasing weed kill as the speed decreased though a complete kill was not obtained with one pass even at the slow speed. The weeds were not consumed by the burning, but were wilted immediately and those that did not survive died in a day or two.

The plots in the pre-emergence burning treatment were burned in the afternoon of the day they were planted, using the 1.13 burning speed. The afternoon was mostly sunny with a few short, cloudy periods and the air temperature was 75 degrees. Three days later the plots were burned a second time as some weeds had survived and as complete a kill as possible was desired. This second burning left the plots practically bare as the weeds killed by the first burning were fairly dry and burned up. The burning did not heat up the ground surface to any extent as a hand could be comfortably laid on the ground almost immediately behind the burner.

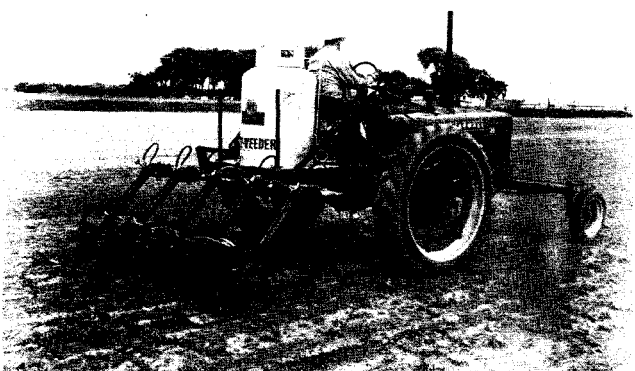

Figure 2. A Sizz-Weeder burner was used for the pre-emergence burning immediately after planting. The stage of weed growth at the time of burning can be noted.

Planting of treatment No. 2, pre-emergence spraying with a herbicide, was done the same as for No. 1 directly in the weed growth as shown in Figure 1. The herbicide selected for this treatment was straight diesel fuel oil to be applied at the rate of 50 gallons per acre. This was recommended by W. W. Robbins of the University of California at Davis based on weed spraying done earlier in the spring at Davis. The plots in this treatment were sprayed with the diesel oil on June 7 in the forenoon of the day following the planting. The day was sunny with a very slight breeze and the air temperature was 72 degrees. Our actual rate of application figured out to be 77 gallons per acre. We wanted to put on enough to get a complete weed kill if possible.

The diesel-oil spray was put on with an Essick Model DFWS-3, air-pressure sprayer mounted on a row crop tractor but driven by a small

auxiliary engine. The unit, which was made available by Bruce Thornton in charge of weed-control investigations at the college, is shown in Figure 3 putting on the pre-emergence spray. A short boom with three Binks nozzles with No. 3 orfice disks was used. These nozzles have a rectangular slot opening averaging .086 by .037 inch and give a flat spray. The nozzles were set 15 inches above the ground to spray nearly directly downward on 25-inch centers and gave a good coverage on the 80-inch, 4-row strip of each beet plot. An air pressure of 50 to 55 pounds per square inch was used which gave a discharge of 2.92 gallons per minute for the three nozzles. The outfit was run at 2.8 miles per hour to give the 77 gallons per acre application rate.

The diesel oil used was purchased locally in Fort Collins from the Continental Oil Company. It came from a Wyoming refinery, we were told, and had the following typical specifications which, of course, are for the oil as a fuel and have little value as specifications for a herbicide:

Flash	154
A. P. I. gravity	40.4
Viscosity at 100 F	
Centistokes	2.53
Saybolt	34.5
Copper strip corrosion test	O. K. non-corrosive
Cetane No.	Corrosive 53-55
Neutralization No.	.025
Sulphur	.05 percent

By June 10 it became evident that our diesel-oil spray was giving very poor weed kill. A check area kept until June 25, shown in Figure 5, showed that we had not gotten but very little weed kill with the diesel-oil spray. The weeds were largely pigeon grass or yellow foxtail, lambs-quarter and wild buckwheat. Apparently the diesel fuel oil which was used was much less toxic to the weeds than that used in tests carried on by the California Agricultural Experiment Station, the Shell Agricultural Laboratory at Modesto, and others in California.

It was desired to get as nearly as possible a complete weed kill by spraying on a herbicide on this treatment. On Bruce Thornton's recommendation, considering dependability and availability of material, it was decided to respray, using a sodium arsenite solution. This spray was applied on June 11, 5 days after planting, but before the beet seedlings were up. The rate of application desired was the equivalent of 100 gallons of 1-percent solution per acre, but we actually put on somewhat more than this to be sure and get a complete weed kill. There was a gentle breeze which gave a little wind drift of the spray, but the spraying could not be delayed as the seedlings would begin to emerge in a day or two. That evening and night 2.5 inches of rain fell which may have made this spray

treatment somewhat less effective. It did cause a heavy soil crust to be formed which had to be mechanically broken on June 16. This reduced the percentage of seedling emergence somewhat.

This spraying gave a fairly complete weed kill, however, and probably would have been slightly better, particularly at the edges of the plot if it had not been for the wind drift of spray. This sodium arsenite spray reduced the seedling emergence somewhat as the percentage of potential emergence on this treatment was 28.4 percent as compared to 40.5 percent on the burned plots which were planted in the same seedbed.

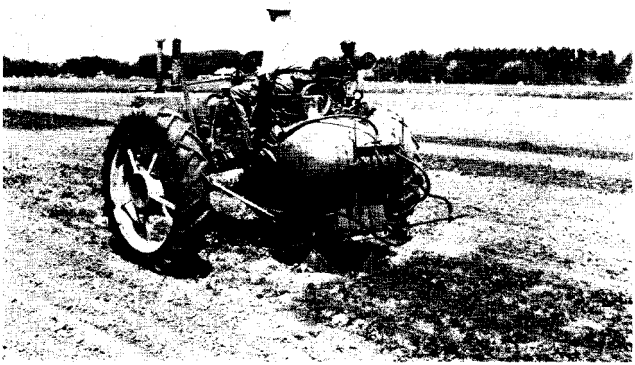

Figure 3.—The pre-emergence diesel fuel-oil spray was applied immediately after planting, the weed growth being in the stage shown.

For the shallow-cultivation weed control, treatment No. 3, the seedbed was cultivated immediately before planting using nearly flat beet-weeder knives and duck-foot knives working just below the soil surface. The depth of cultivation averaged about 1 inch. The soil was disturbed very little by this cultivation, in fact not enough to kill all the weeds cut off. The ground was moist and some of these weeds continued to grow after the cultivation. The appearance of the seedbed of this treatment after cultivation and planting is shown at the right side of Figure 1.

Treatment No. 4 was planned to be one type of check as it was one method of clean-up of seedbeds which have had to lie or been allowed to lie, after fitting and before planting, and on which the weeds have

sprouted. The seedbed preparation was similar to that of treatment No. 3 except that the shallow-cultivation was followed by spike-tooth harrowing to comb out the weeds cut off and perhaps bring up more weed seed. However, the harrowing was not deep enough apparently to bring up more weed seed or at least unsprouted seed as few new weeds sprouted after this operation. It developed into virtually a more thorough shallow-cultivation than treatment No. 3. The seedling emergence on both treatments Nos. 3 and 4 was poorer than where the seed was planted in the undisturbed seedbed and weed growth on treatments Nos. 1 and 2. The emergence was only 18.6 percent on No. 3, shallow-cultivated, and was 28.2 percent on No. 4 which was both shallow-cultivated and spike-tooth harrowed.

Treatment No. 5 was a covered-row treatment which has been advocated for weed control in the beet row. It consists of throwing a ridge of soil over the planted row at planting time and removing this ridge in about 4 or 5 days just before the beet seedlings develop far enough to emerge from the original level of the seedbed. There are two possible ways in which the covered-row method of planting might aid in weed control. One is that the ridge thrown up covers the small weeds in the row and smothers them before the ridge is removed. The other involves destruction of the weeds by seedbed fitting prior to planting. The ridge over the row prevents the weed seeds in the row from germinating while the beet seed is germinating. When the ridge is removed, just before the beet seedlings are ready to emerge, any weeds which have sprouted on the ridge will be killed. The beet seedlings will then get ahead of the weeds sprouting later in the row.

Our covered-type treatment was planted directly in the undisturbed, weedy seedbed as shown in Figure 4. The small disks had to be weighted to penetrate, but threw up a very satisfactory small ridge about 2 inches high as shown. These ridges quite effectively covered the weeds in the row, but as they had to be removed on June 10, 4 days after planting, to avoid damage to the sprouting beet seedlings when removing the ridges, the weeds were not covered long enough to be killed. The ridges were removed with vertical blades about 12 inches long set at right angles to the rows and mounted on a tractor-mounted beet cultivator by standards and clamps. These blades actually scraped the original surface of the ground when removing the ridges and thereby scraped off and killed some of the weeds in the beet rows. The seedling emergence on this treatment was 32.1 percent as compared with 40.5 percent on the burned plots.

Treatment No. 6 was a check on which the beets were planted in the undisturbed, weedy seedbed the same as for the burning and spraying treatments. No weed control treatment was practiced at planting time.

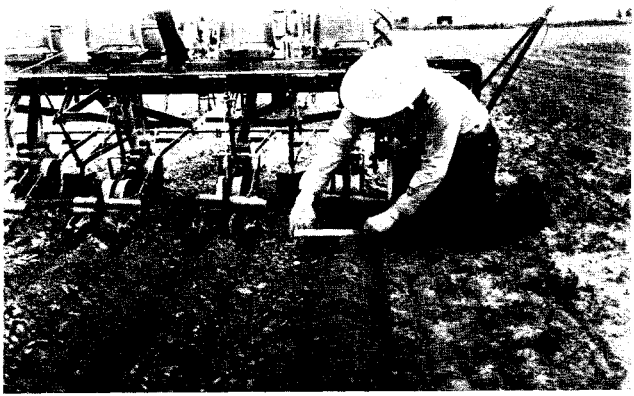

Figure 4.—A pair of small disks, weighted to improve penetration, was used at the rear of each furrow opener for the covered-row planting.

No thinning was done on these plots. The unthinned beet stands in seedlings per 100 feet on the six treatments were as follows:

1.	Pre-emergence burning	136
2.	Pre-emergence spraying	95
3.	Shallow-cultivation just before planting	86
4.	Shallow-cultivation and spike-tooth harrowing before planting	95
5.	Covered-row planting	107
6.	Check	....

The measure of effectiveness of the weed-control treatments was taken as the time required to clean up the plots by hand hoeing. It was decided that no good beet grower would allow even the cleanest of the plots to go through to harvest without hoeing out the weeds. Therefore, all of the plots were cleaned up free of weeds. The weediest treatments were hoed on June 25 and 26. The No. 6 check treatment shown in Figure 5 was so weedy that it had to be very carefully cleaned up by short handled hoe and hand weed pulling and even then some of the beets were pulled out by mistake.

All of the plots were gone over on July 9, just over a month after planting, with long-handled hoes, to cut out all remaining weeds. This was the first and only hand work done on the burned, No. 1, and cultivated and harrowed, No. 4, treatments and, as can be seen at the right

in Figure 5, little hoeing was necessary. The sprayed plots had been hoed on June 26, chiefly to clean up the edges of the plots where the spray had apparently missed because of wind drift, but comparatively little labor had been required. The clean-up time for the different treatments was obtained by totaling all hand-labor time used on the plots. The time for all the plots is comparatively high as inexperienced high-school boys were used for most of the work and the clean-up was thoroughly done, but the comparative times required for different treatments are indicative of the difference in weediness of the plots.

Figure 5.—The weed growth on the check plot which received no weed-control treatment had progressed to this stage by 19 days after planting. The four-row plot on the right of the check was cultivated and harrowed before planting, the next to the right was a burned plot and the plot at the left was covered-row planting.

The hand labor required to clean up the different treatments free of weeds is shown in table 1. The difference required for significance at the 95-percent level, shown at the bottom of the table, indicates no significant difference between weed control by burning and by weed elimination just before planting by shallow-cultivation and harrowing. This weed control by shallow cultivation just before planting might have been less effective if the planting had gone in a month or more earlier when weed-seed germination conditions before planting would have been less favorable. A shallow working of the soil at the earlier date might have moved unsprouted weed seed to a more favorable location for later germination and growth. This is just one of the unanswered questions in connection with this work.

Table 1. Hand labor required for weed clean-up.

No.	Treatment Description	Man hours per acre	Percent of minimum
1.	Pre-emergence burning	14.57	104
2.	Pre-emergence spraying	21.65	155
3.	Shallow-cultivation before planting	45.21	324
4.	Shallow-cultivation and harrowing	13.98	100
5.	Covered-row planting	51.03	363
6.	No weed control	189.50	1355
	Difference for significance	2.12	

If the spraying had given complete weed kill to the edges of the plots, less time undoubtedly would have been required to clean up the sprayed plots and they probably would have required about the same time as the burned and clean-cultivated plots. Weed control by shallow-cultivation where the weeds were not killed or by the type of covered-row planting used was much less effective than the treatments just mentioned as shown by the data. The weediness of the No. 6 treatment, where no weed control was practiced at planting time, is indicated by the extremely large amount of time required to clean it up. However, this is of little practical concern as no beet grower would have planted in the weedy seedbed without cleaning it up at planting time.

The amount of labor required to clean up the weeds in the beet plots, that is about 14 man-hours per acre, might seem to indicate that it would have been almost as well to have used a heavier seeding rate and thin the beets in the usual manner, thereby hoeing the weeds out of the beet rows. However, this was not the case. No cultivating for weed control had been done on these beets, or was done later for that matter, and the time required was for hoeing weeds out of the spaces between the rows as well as in the rows. Then, too, the work was done by low-capacity labor.

The beets in all the plots came along well, probably getting a better start because of the small amount of fertilizer used at planting time. They made a good seasonal growth in spite of the late planting and yielded around 13 tons per acre, about 1 ton per acre less than the factory district average. No separate treatment yields were taken as all plots were practically alike after the weeds were cleaned up.

Not much information could be obtained on the economics of the different treatments as the plots were small. However, some information is available. The Sizz-Weeder used at the rate of approximately 90 pounds or 21.3 gallons of propane per hour with 35 pounds per square inch of gas pressure using all eight burners of the machine. At our fuel cost of 12 cents per gallon in lots over 50 gallons, the cost per hour was $2.56. At a speed of 1.13 miles per hour and a width of coverage of 80 inches, the acreage covered was .91 acre per hour while actually burning, which would take 23.4 gallons per acre would cost $2.81 per acre for one burning. One burning at this rate did not give us a complete weed kill so the plots were burned twice at a fuel cost of $5.62 per acre. However, if two

burnings are necessary, the comparatively small amount of difference between the degrees of kill at 1.13 and 2.5 to 3 miles per hour would indicate that two burnings at higher rates of speed separated by 2 or 3 days might be just as effective as the two at 1.13 miles per hour. During the interval between burnings, much of the weed growth dies and dries so apparently the second burning is more effective than the first. If pre-emergence burning were to be the answer to weed control, considerable more experimentation will be necessary to determine the most effective and economical speeds and burner adjustments.

The spraying treatment of 77 gallons of diesel fuel per acre which was used was not effective in obtaining a satisfactory weed kill. However, others have obtained 97 percent or better weed kill with 50 gallons of diesel fuel per acre, apparently using a more toxic oil than the diesel fuel we used. Assuming that a fuel oil toxic to weeds was available at the same 11 cents per gallon price we paid, the cost of oil for spraying would be $5.50 per acre at the 50-gallon rate. Our rate of application was 2.26 acres per hour, but could be considerably greater by using a longer spray boom with more nozzles covering a wider strip. The sprayer we used probably could have handled 10 to 12 nozzles at the 50 to 55 pounds per square inch pressure used which would have covered around 8 acres per hour at the 2.8 miles per hour speed used when actually spraying. The daily capacity of a spray outfit would of course depend upon the speed and size and the time lost in refilling.

The cost of shallow-cultivation just before planting would depend upon the size of equipment used and speed of travel. It should average somewhat less than the cheapest beet cultivation as the rate of travel could be considerably higher. Covered-row planting would cost little if any more than regular planting after the equipment were purchased. The operation of removing the ridges as we did would cost about the same as beet cultivation. There is a real danger with the covered-row planting which should be mentioned, particularly with early plantings when rains may delay removal of ridges. If we had not removed our ridges on the day we did, the 2.5-inch rain the next day would have kept us out of the field until the ridges could not have been removed without damaging the beet seedlings. The seedlings would have had to come through 2.5 to 3 inches of soil and many would never have lived to emerge.