Stand and Yield of Sugar Beets, and Weed Populations as Affected by: Broadcast Fertilization, Mechanical Thinning, Application of Herbicides and Their Interactions[1]

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Spring mechanization of sugar beet production has been the subject of considerable experimental work in recent years. Various recommendations concerning mechanical thinning and chemical weed control have been based on results from these experiments. A cooperative experiment was conducted to test combinations of some of the most promising recommendations. Three mechanical thinning" treatments and both pre- and post-emergence applications of herbicidal sprays with suitable checks were tested on four rates of fertilization at East Lansing, Michigan.

Experimental Design and Methods

The experiment was set up as a multiple-split plot randomized block design with eight replications of the main (fertilizer) plots. The main plots were twelve rows wide and 320 feet long. These main plots were split into three subplots (thinning) which were four rows wide and 320 feet long. The main plots were split in half lengthwise for post-emergence spray treatments (plots *12* rows wide and 160 feet long). These post-emergence spray plots were split in half again for pre-emergence spray treatments (plots 12 rows wide and 80 feet long) .

A black root resistant variety of sugar beets, U. S. 400, was used. Processed seed, treated with a fungicide, was drilled at a depth of one inch in 28-inch rows at the rate of 5 pounds per acre. All plots received 200 pounds of 3-18-9 fertilizer per acre placed with the seed.

Experimental treatments in the order of splits in the design were as follows:

Fertilizer

F_x—0, F_2—500, F_3—**1,000,** and **F_4—**2,000 pounds per acre of 3-18-9 broadcast with a grain drill before seeding.

Mechanical Thinning

T_1—Spring-tined heads spacing cuts across the row $2^1/_2$ inches apart for each of the two counter-rotating heads (this approximates two operations with a single head machine) . Subsequently, these plots were blocked and thinned by hand labor.

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T_2 Spring-tined counter-rotating heads with the spacing of the cuts across the row regulated at the discretion of the operator to compensate for variation in density of the beet stand. These plots were also blocked and thinned by hand labor.

T_3—Spring-tined counter-rotating heads with the spacing of the cuts across the row regulated at the discretion of the operator to compensate for variation in density of the beet stand. This treatment received no further blocking and thinning by hand labor.

All plots were hand hoed, to remove weeds after stand counts of beets and weeds had been made.

The thinner (l)[3] used in this experiment has two counter-rotating heads for each row and a variable speed drive. The rate of rotation can be changed quickly without interruption of the thinning and weeding action. This two-row machine is midmounted on the tractor and is driven by the power takeoff shaft. The depth-gauge wheels were adjusted to permit the spring tines to penetrate the soil to a depth of 1 inch for all of the thinnings. The tractor was operated in second gear at a speed of 2.8 miles per hour.

Post-Emergence Herbicidal Spray

A_1—a mixture of 5 pounds sodium trichloroacetate (TCA), 2 pounds of endothal and 30 gallons of water per acre.

A_2—No post-emergence herbicidal spray.

The sprayer was mounted on the tractor immediately behind the thinner heads with separate controls for the thinner and sprayer such that either operation could be used independently or both used simultaneously.

Pre-Emergence Herbicidal Spray

P_1—5 pounds TCA, 2 pounds sodium pentachlorophenate (PCP) and 40 gallons of water per acre.

P_2—No pre-emergence herbicidal spray.

All herbicidal sprays were applied in a 6-inch band centered over the row.

In order to determine the effectiveness of the pre-emergence spray and to establish a basis for evaluating the methods of thinning and effects of post-emergence sprays, stand counts of grasses, broad-leaved weeds, and beets were made. Permanent sites were established in each plot and all plant counts were made at these locations. Beet counts were made in 100-inch row lengths in both center rows of each plot. Within this area of a plot, weed counts were made on 6 sites, 4 inches by 12 inches, centered lengthwise on the row. A second count was made after mechanical thinning and post-emergence spraying had been completed. After the second counts had been made, the plots were given cultivation and hand hoeing as required to control weeds. The beets in each plot were counted again just before harvest. At harvest, root yields, number of marketable beets, sucrose percentage, and purity were determined for each plot.

[8] Numbers in parentheses refer to literature cited.

Summary of Variables

F_1—No fertilizer.
F_2—500 pound per acre 3-18-9 broadcast.
F_3—1,000 pounds per acre 3-18-9 broadcast.
F_4—2,000 pounds per acre 3-18-9 broadcast.
T_1—Fixed speed mechanical thinning, hand blocking and thinning.
T_2—Variable speed mechanical thinning, hand blocking and thinning.
T_3—Variable speed mechanical thinning, no hand blocking or hand thinning.
A_1—Post-emergence spray.
A_2—No post-emergence spray.
P_1—Pre-emergence spray.
P_2—No pre-emergence spray.

Schedule of Operations

OPERATIONS	DATE
Planting	May 25
Pre-emergence spray	May 29
First count (beets, grasses, broad-leaved weeds)	June **11-12**
Mechanical thinning, Post-emergence spray	june 12-13
Second count (beets, grasses, broad-leaved weeds)	June 24-25
Hand hoeing all plots (weeds only)	July 7-9
Hand blocking and thinning stand of beets (T_1 and T_2 only) "	July 16-17
Pre-harvest count of beets	Sept. 28 to Oct. 3
Harvesting	Oct. 5 **to** 15

Discussion of Results

A. Broadcast Fertilizer.

Although there was a significant increase *in* yield from fertilizer (Table 1) , the broadcast method of fertilization did not give a profitable return under the conditions of this experiment. It should be pointed out, however, that the broadcast fertilization gave varying nutrient levels with which to assess the relative importance of beet-weed competition for nutrients. This will be discussed later under interactions.

B. Thinning Treatments

Statistically significant differences between treatments were obtained for: stand before harvest, number of marketable beets, percentage of marketable beets, tons of roots, and gross and net sucrose[4] (Table 1) . The lower yield of T_3 plots probably was a result of uneven distribution of the beets, which led to severe competition where they were bunched together, rather than a result of greater numbers of beets. The differences between thinnings, shown at harvest, can be ascribed to hand blocking and thinning since stand differences between the three treatments at the time of the second count were not significant. Proportionately greater removal of broad-leaved weeds, as compared to grasses, was effected by mechanical thinning. This can be observed in the "no spray" treatment of Table 2.

[4] Gross sucrose x percentage purity.

Table 1.—Numbers of Sugar Beet Roots, Yields, and Percentages of Sucrose and Purity as Affected by Fertilization, Thinning, and Herbicidal Sprays.

	Fertilizers				L.S.D.		Thinnings			L.S.D.	
	F_1	F_2	F_3	F_4	5%	1%	T_1	T_2	T_3	5%	1%
Stand before Harvest (per 100')	76.5	75.6	88.1	87.5	N.S.	N.S.	81.3	73.1	93.3	6.2	8.3
Number Marketable Beets (per 100')	61.5	62.4	73.9	70.9	8.8	N.S.	66.5	62.8	72.2	3.4	4.6
Percent Marketable Beets	84.3	84.9	84.3	84.6	N.S.	N.S.	85.0	87.7	80.9	1.9	2.5
Tons of Roots per Acre	8.50	9.04	10.01	10.20	.68	.92	9.69	9.67	8.95	.37	.49
Gross Sucrose (pounds per acre)	2,682	2,820	3,194	3,181	235	318	3,052	3,034	2,821	114	152
Net Sucrose (pounds per acre)	2,118	2,237	2,541	2,482	195	264	2,411	2,392	2,231	88	117
Percent Sucrose	15.77	15.54	16.02	15.57	N.S.	N.S.	15.72	15.70	15.76	N.S.	N.S.
Percent Purity	78.84	79.13	79.38	77.82	N.S.	N.S.	78.82	78.65	78.92	N.S.	N.S.

	Herbicidal Sprays							
	Pre-emergence		L.S.D.		Post-emergence		L.S.D.	
	P_1	P_2	5%	1%	A_1	A_2	5%	1%
Stand before Harvest (per 100')	80.3	85.0	3.3	4.4	73.4	91.8	4.7	6.4
Number Marketable Beets (per 100')	65.8	68.5	2.6	N.S.	60.4	73.9	3.2	4.3
Percent Marketable Beets	85.7	83.3	1.2	1.6	85.3	83,7	1.8	2.4
Tons of Roots per Acre	9.68	9.19	.28	.37	8.87	10.00	.56	.77
Gross Sucrose (pounds per acre)	3,029	2,909	102	N.S.	2,749	3,190	175	236
Net Sucrose (pounds per acre)	2,386	2,303	N.S.	N.S.	2,157	2,533	136	197
Percent Sucrose	15.62	15.84	.15	.19	15.51	15.95	.26	.35
Percent Purity	78.52	79.07	.44	N.S.	78.27	79.32	.67	.90

Table 2.—The Effects of Herbicidal Sprays on Weed and Sugar Beet Stand, Yield, and Sugar Production.

	Weeds Per 100 feet of 4-inch strip centered on row.											
	Grasses		Broad-leaved				Beets Per 100' of Row		Tons Acre	Percent	Percent	Net
	1st	2nd	1st	2nd			1st	2nd	Beets	Sucrose	Purity	Sugar
Pre-plus Post-emergence	35.3	4.0	866.6	135.2	902.9	139.2	370.8	113.6	8.9	15.43	77.94	2,144
Pre-emergence	49.3	22.0	834.5	168.7	883.8	190.7	380.9	144.2	10.5	15.82	79.14	2,629
Post-emergence	601.5	230.7	2,049.0	315.1	2,650.5	545.8	447.3	149.7	8.8	15.59	78.64	2,170
No spray	515.1	237.5	1,928.0	447.7	2,443.1	685.2	450.2	185.8	9.5	16.09	79.55	2,437

[1] At the first count only the pre-emergence spray had been applied. Data for pre- plus post- and post-emergence spray are included to give a basis for evaluating the second count since the initial stands could not be assumed to be uniform. It should be noted also that mechanical thinning between the first and second counts reduced weed and beet counts of all treatments.

Thinning treatments T_1 and T_2 required 22.8 additional man hours per acre for blocking and thinning. Thus, T_1 and T_2 cost $15.90 more per acre than T_3 which received only mechanical thinning. This additional cost was not offset by the income from the significantly higher yields (Table 1) of T_1 and T_2 over T_3. As mentioned previously, thinning method T_3 was performed with a variable speed thinner; therefore, operator skill influenced these results.

C. Herbicidal Application

In Table 2, the data have been arranged to show the effects of pre-emergence, post-emergence, and a combination of the two treatments in comparison with no herbicidal spray. These pooled values include all rates of fertilization and all thinning methods.

The combination of TCA and PCP, as a pre-emergence spray, gave excellent control of grasses at the time of beet emergence and this herbicidal treatment continued to retard the emergence of weeds for approximately one month. The control of broad-leaved weeds was not equal to that of grasses but measurable effects were obtained. Sufficient weed control was obtained from the pre-emergence treatment to significantly increase root yields. This effect on root yields was initiated early in the growing season, since weeds were removed by hand labor 6 weeks after planting. This is one of the most important results of the experiment.

Post-emergence spraying generally gave good control of broad-leaved weeds and lesser effects on grasses present at the time of spraying. Field observations, however, indicated that late grass emergence was reduced *in* the sprayed plots. This effect probably was due to some residual effect of the TCA. Some burning was observed on the beet leaves but this injury did not visibly affect the subsequent top growth of the beet seedlings.

The combination of pre- and post-emergence sprays brought about the greatest reduction in stand of weeds and of beets. Enough beets were left, however, to produce an acceptable commercial stand. Yields of beets were reduced significantly as a result of post-emergence spraying. Pre-emergence spraying alone gave a significant increase in acre yield of roots and in percentage of marketable beets.

Herbicidal treatments caused a significant, 1 percent level, reduction in sucrose percentages and purity coefficients. Post-emergence spraying reduced the net sugar production whereas pre-emergence spraying did not.

Data obtained at harvest indicate that post-emergence sprays may have produced some fundamental effects upon the physiological activity of the beets. This is reflected in the lower yield of beets, percentage sucrose and purity, and net sugar. Immediately after the spray application some leaf injury was observed but as the season advanced the sprayed beets were not visibly different from the unsprayed beets.

Unpublished data [5] have shown that endothal also may have marked effects upon some cell processes, especially on mitotic division. Thus, dis-

[3] Personal communication from G. B. Wilson, cytologist, Department of Botany and Plant Pathology, Michigan State College.

turbances in the manufacture or movement of materials within the plants may have occurred. The data do not permit a determination of the direct cause. Further studies of the effects of herbicides upon the growth of sugar beets are needed before general use of post-emergence sprays is recommended.

The effects of combined pre- and post-emergence sprays appear to be merely additive, and with no marked interaction. It is possible that in this experiment there was some carry-over effect on grass emergence but no other important effects were observed.

While time-lapse studies were not made, the reductions in weed population, following pre-emergence treatment, were large enough to suggest that substantial savings in time required for weed removal were effected.

D. Interactions

The main factors which interacted to influence the yield are given below:

1. Early plant competition.

Early competition among all plants, beets and weeds could be measured by comparing the yields of those plots receiving only a

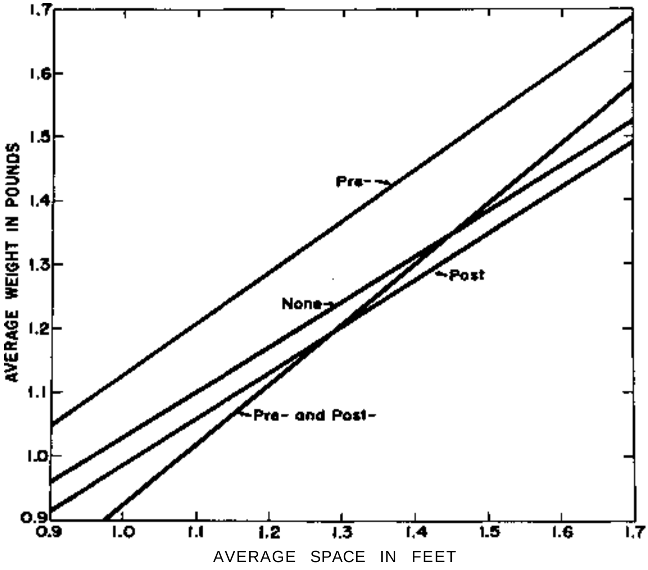

Figure 1.

pre-emergence spray with those receiving no herbicidal spray. Competition in the first few weeks after planting gave a negative correlation (—.48, significant at the 2 percent level) with the final yield. As might be expected, the correlation was highest with no broadcast fertilization (—.975, significant at the 1 percent level). Those plots receiving post-emergence spray were omitted from the above calculations due to the detrimental effect of the spray.

2. Effect of the post-emergence spray.

In Figure 1, the slopes of the lines were not significantly different from each other. While the pre-emergence (pre-emergence only) treated beets were larger for any given spacing, subsequent application of a post-emergence treatment (pre- plus post-emergence) counteracted the advantage of the preemergence treatment. This apparent decrease in weight-space response appears as indicative of at least a temporary upset in the metabolism of the beets. It should also be noted (Figure 3) that in general the number of beets at harvest was lower whenever a post-emergence treatment was applied. These two effects are evident in the yield data (Figure 4) at the higher rates of fertilization. Where there was no broadcast fertilization, early plant competition played a dominant role in determining the final yield, thus masking the effect of the post-emergence treatment.

3. **Competition among the beets.**

The competition of beets among themselves after thinning affected yield. This is especially evident in the T_3 plots where local crowding of beets was judged to be primarily responsible for the decreased yield.

With the above interactions in mind it is possible to evaluate the yield data (Figure 4) on the basis of the integrated effect of early competition (Figure 2), beet stands at harvest (Figure 3), the weight-space ratio (Figure 1), and the local crowding observed in the T_3 plots.

The consistently greater yield of plots receiving only pre-emergence spray may be attributed most logically to the reduced early competition from weeds. The unsprayed treatment was consistently next highest in yield. The early competition from weeds apparently reduced this yield as compared to plots receiving only pre-emergence spray. The plots receiving a post-emergence spray yielded the least.

In general, the effect of the post-emergence spray treatment was so pronounced that the potential advantage of the pre-emergence spray in reducing early competition as compared to no pre-emergence spray was obscured. The lower yield of the post-emergence spray plots apparently resulted from an adverse effect on weight as shown by the weight-space ratio and also from a slight reduction in number of beets.

In the plots receiving no broadcast fertilization, the above trends were largely obscured by the severe competition for nutrients, especially during the early stages of plant growth. In contrast, early competition appears to be less of a factor where more nutrients are available since the yield of the unspraved plots tended to approach the yield of the pre-emergence sprayed plots at the highest rate of fertilization.

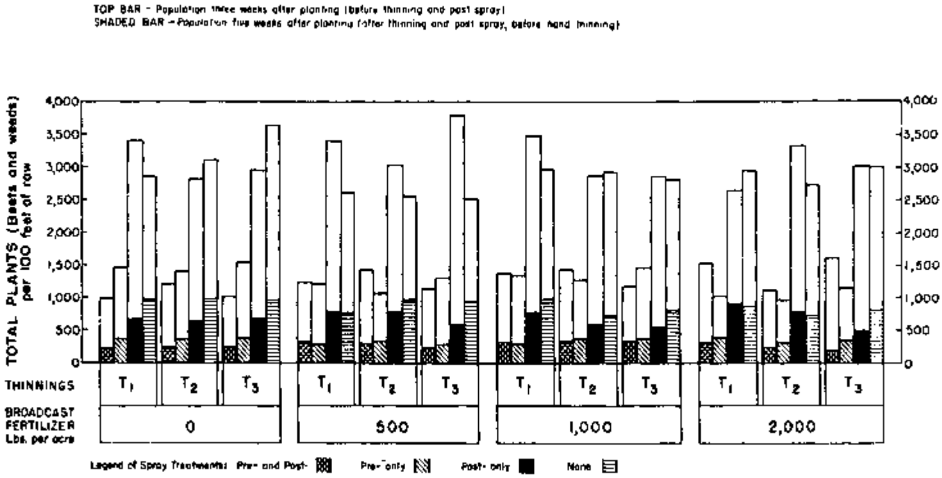
TOP BAR - Population three weeks after planting (before thinning and post spray)
SHADED BAR - Population five weeks after planting (after thinning and post spray, before hand thinning)
TOTAL PLANTS (Beets and weeds) per 100 feet of row
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
THINNINGS
T1
T2
T3
BROADCAST FERTILIZER Lbs. per acre
0
500
1,000
2,000
Legend of Spray Treatments: Pre- and Post-
Pre- only
Post- only
None

Figure 2.

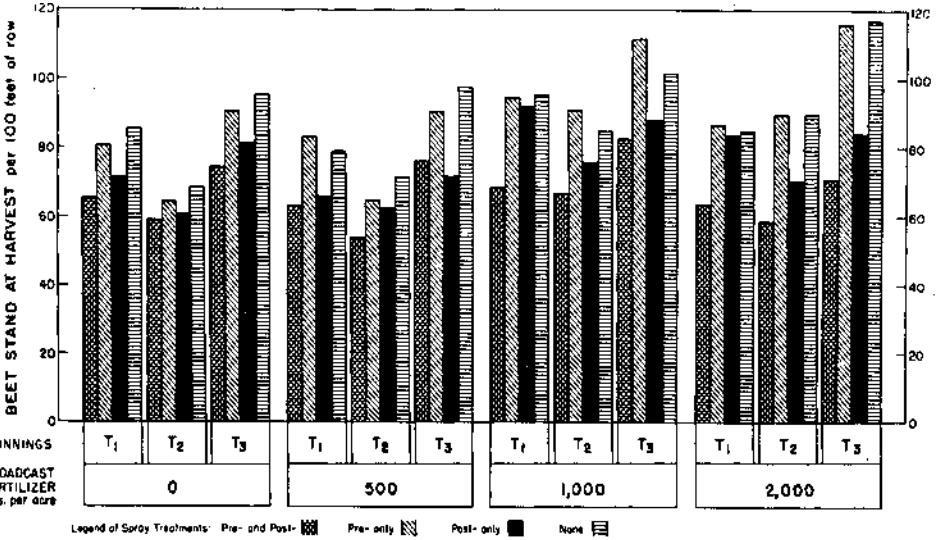
BEET STAND AT HARVEST per 100 feet of row
0
20
40
60
80
100
120
THINNINGS
T1 T2 T3
BROADCAST FERTILIZER Lbs. per acre
0
500
1,000
2,000
Legend of Spray Treatments: Pre- and Post-
Pre- only
Post- only
None

Figure 3.

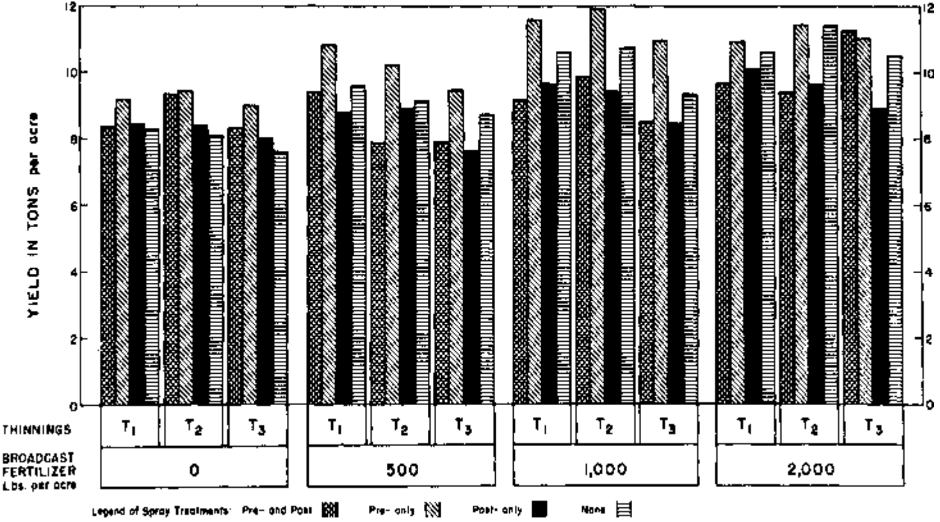
YIELD IN TONS per acre
0
2
4
6
8
10
12
THINNINGS
T1
T2
T3
BROADCAST FERTILIZER Lbs. per acre
0
500
1,000
2,000
Legend of Spray Treatments: Pre- and Post
Pre- only
Post- only
None

Figure 4.

Summary

1. Broadcast fertilization at the rates of 1,000 and 2,000 pounds per acre significantly increased the yield over rates of 0 and 500 pounds per acre.

2. Broadcast fertilization was not an economical method of applying fertilizer.

3. The mechanically thinned plots receiving additional hand labor for blocking and thinning yielded significantly more than those plots thinned entirely by machine. However, under the conditions of this experiment, the increase in yield was insufficient to pay for the cost of the additional labor.

4. All three mechanical thinning treatments were more effective in reducing the populations of broad-leaved weeds than that of grasses.

5. Pre-emergence applications of a mixture of TCA-PCP gave effective control of grasses and a less satisfactory control of other weeds.

6. Beet stands were reduced by pre-emergence sprays but stands were adequate to produce a good yield of beets.

7. Yields were significantly increased by pre-emergence spraying.

8. Pre-emergence application of a mixture of TCA and PCP gave effective control of weeds in sugar beets and this mixture of herbicides is suggested for grower use.

9. Post-emergence spraying with a mixture of TCA and endothal gave control of broad-leaved weeds but was not satisfactory for grasses.

10. Post-emergence spraying reduced the yield of beets and affected adversely sucrose and purity percentage with a resultant decrease in net sugar.

11. The post-emergence herbicide may have upset the metabolism of the beets, since, for any given spacing, the postemergence sprayed beets weighed less than the unsprayed beets.

12. Post-emergence applications of a mixture of TCA and endothal is not recommended.

13. Early plant competition among beets and weeds gave a significant negative correlation with yield. This correlation was most pronounced at the lower fertility levels.

14. The local, severe crowding of beets, particularly evident in the ail-mechanically thinned plots, apparently affected yield adversely.

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