OBSERVATIONAL STUDIES ON THE MECHANIZATION OF THE SUGAR BEET CROP

THESIS FOR THE DEGREE OF M. S.
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ALLAN W. STOBBS

1955

This is to certify that the

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S. T. Dexter
Major professor

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OBSERVATIONAL STUDIES
ON THE
MECHANIZATION OF THE SUGAR BEET CROP

by

Allan W. Stobbs

An Abstract

Submitted to the School of Graduate Studies of

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Sugar beet production is characterized by seasonal peaks of labor requirements. Rapid progress has been made since 1945 in removing those peaks by the development of mechanical devices to treat the seed, and plant, thin, and harvest the crop. These aspects are dealt with in the following order:

Part I

Sugar-beet seed, processed at the Farmers and Manufacturers seed plant at Saginaw, was graded according to size from less than 7/64 inch in diameter to 13/64 inch. The percentages by weight of each grade in natural, processed, and intermediate seed was determined. Selected grades of seed were germinated in the greenhouse in order to determine the numbers of single, double, triple, etc., sprouts each grade was capable of producing.

It was found that: (1) processing did not seriously impair germination, (2) 72 percent of the viable units were recovered in the processing operation, and, (3) processing increased the number of singles by 30 percent.

Part II

Field observations were made on the operations of Palsgrove and International planters and the "Dixie" type thinner in Huron and Tuscola counties. Results indicated the value of precision planting and mechanical thinning under ideal field conditions. The disadvantages of these machines showed up in a striking manner under conditions that were less than perfect.

Part III

Observations were made on four types of mechanical harvesters at work during the 1954 harvest period. A description is given of each machine together with information on the weights of tare and dirt which each machine lifted. An analysis of these results showed little variation between the four types but did show up other factors affecting the cleanliness of harvested beets. It was concluded that although hand labor made a cleaner job of harvesting it was doubtful whether the value of clean beets would offset the extra cost in money, time and patience involved in using hand labor.

All three studies showed the close tie-up and interrelation between one phase of beet growing and another, and how, for example, a new development in planting technique influences the subsequent operations of thinning and harvesting.

OBSERVATIONAL STUDIES ON THE MECHANIZATION OF THE SUGAR BEET CROP

by

Allan W. Stobbs B.Sc.(Dunelm)

A Thesis

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Finally, the author wishes to place on record his gratitude to all the members of the staff of the Farm Crops Department who, through their friendship and help, have made his sojourn in the United States such a pleasant one.

CONTENTS

INTRODUCTION

In presenting this report on "Observational Studies on the Mechanization of the Sugar Beet Crop," it is thought necessary to offer some explanation for the choice of subject.

Beta vulgaris (sugar beet) has been grown for the extraction of sucrose since Napoleonic times. During the period of the last one hundred and fifty years, the cultivation of this crop has spread throughout Europe and North America.

Sugar beet production in the United States presents many interesting features, not the least of which is the very high degree of mechanization associated with the crop. There is no doubt that this development of methods by which hand labor requirements can be reduced has been forced upon the American sugar beet grower by the shortage, and consequent high price, of hand labor.

In the United Kingdom, on the other hand, the supply of labor has been relatively cheap and plentiful so that there has not been the same incentive towards mechanization in that country as there has been in the United States. For example, it was estimated that 63 percent of the United States sugar beet crop was lifted by mechanical harvesters in 1951; in the United Kingdom only 20 percent of the crop was harvested by machine in that year.

During recent years, the price of labor in the United

Kingdom has been increasing at a rate out of proportion to the value of the crop so that the need for greater mechanization is becoming increasingly apparent. Consequently, a study of recent developments in the growing of the sugar beet in the United States would be of considerable value to growers of the crop in the United Kingdom.

With this object in mind and through facilities made available by the W. K. Kellogg Foundation, it was possible to make a series of observations on sugar beet production in Michigan. The following is a report on the findings of these observational studies.

PART I

PROCESSED SUGAR BEET SEED

The so-called "seed" of the sugar beet is most peculiar when compared with those of other farm crops being neither uniform in size nor germination. In its natural form, the "seed" of commerce is really a seed-ball or fruit composed of a number of germs each enclosed in a woody outer covering or husk.

For the purpose of this thesis, the word seed will be used to describe all viable units, regardless of whether they produce one, two, three, or more sprouts.

On germination, each seed-ball may produce from one to seven beet seedlings, depending upon the number of viable germs in the fruit, and consequently such seed causes a great deal of work when the resultant crop is thinned, work that is intricate, costly, and laborious.

The processing of sugar beet seed was introduced to obtain a larger proportion of single-germ units by which it was hoped to reduce labor requirements for thinning.

The relative value of sugar beet seed to a grower will depend (generic factors apart) on whether he requires:

a) High germination, irrespective of the number of sprouts per seed-ball.

b) An even distribution of singles and doubles.

c) The maximum number of singles, irrespective of germination.

The purpose of this study, then, is twofold:

1. To make a comparison between natural and processed seed with regard to germination capacity and density of stand.
2. To examine the present processing operation with a view to making possible improvements.

REVIEW OF LITERATURE

In an effort to further the movement towards mechanization, work was carried out in 1940 and 1941 at the California Agricultural Experiment Station by Bainer (1) on the processing of sugar beet seed by passing it through a machine which "cracked" or "segmented" the seed-ball. The effect was to break the fruits up into pieces containing fewer germs, with subsequent variations in germination capacity. With the exception of 4.4 percent of the sample that failed to go through the 11/64 inch sieve, the germination was reduced and the number of seedlings per seed-ball was halved from 2.21 in the original to 1.18 and 1.05 in the "cracked" seed. Table I.

TABLE I

Results of cleaning, grading, and germination of a sample of "cracked" beet seed. - after Bainer (1)

Grade - Sieve	% Retained	% Germination	Seedlings/Ball
Over 11/64 inch	4.4	94.0	1.76
11/64 inch - 8/64 inch	42.2	82.1	1.18

TABLE I (Continued)

Grade - Sieve	% Retained	% Germination	Seedlings/Ball
8/64 inch - 6/64 inch	10.8	53.8	1.05
Free Germs	2.9	71.0	1.00
Dust & Screenings	39.7		
Original Sample	100.0	84.5	2.21

It is interesting to note that the large seed, over 11/64 inch in size, had a higher germination than the original which was in contrast to the findings of Lynes at Wyoming (2). He found that the germination of natural seed (without being treated) rose from 56 percent in the original sample to 82 percent for the fraction between 9/64 and 11/64 inch in size. Unfortunately, Lynes does not give any information on the number of seedlings per seed-ball given by his re-graded seed.

Price and Carsner (3) found that under critical greenhouse examination large seed-balls (those remaining on the 4 m.m. or 10/64 inch sieve) gave more rapid germination and produced more vigorous seedlings than small seed-balls (those remaining on the 2.5 m.m. or 6.3/64 inch sieve). They deduced from this that gains in yields of beets and sugar accruing from the use of larger seed would far more than offset losses involved in discarding the smallest and weakest seed - 2.5 m.m. or 6.3/64 inch. They concluded that when seed is to be segmented it would seem obviously advantageous to size the seed first, discard the small fractions, and segment only the larger sizes.

Segmented seed was widely introduced in 1942 with the aim of procuring as many single plants as possible in the sugar beet crop. In order to obtain a seed with a high percentage of single germ pieces, it was necessary to give the natural seed harsh treatment in the segmenting process and consequently germination was far from satisfactory.

More recently Frakes (4) and Ryser and Owen (5) have shown that yields are not appreciably affected by leaving up to 30 percent of doubles. Consequently, the aim in seed processing has been shifted from producing seed with a high percentage of singles and low germination to seed as uniform in shape and size as possible containing up to 50 percent of doubles and a high germination (6).

SEED PROCESSING

1) Description of the operation.

The processing of natural sugar beet seed was carried out at the seed-processing plant of the Farmers and Manufacturers Beet Sugar Association at Saginaw. The machinery used consisted of three sets of burrs and pressure plates and two Clipper mills set out as shown in the diagram. Power was provided by two 7½ H.P. electric motors.

Natural seed (variety U.S. 400) was fed by bucket-type elevator from a hopper in the floor to the top of the first clipper mill. Two screens separated the seed into three fractions: over 13/64 inch, 7/64 inch - 13/64 inch, and less than 7/64 inch. The large sized seed (over 13/64 inch) passed down into the first burr and pressure plate before falling, at B, into an auger-type conveyor running the length of the floor.

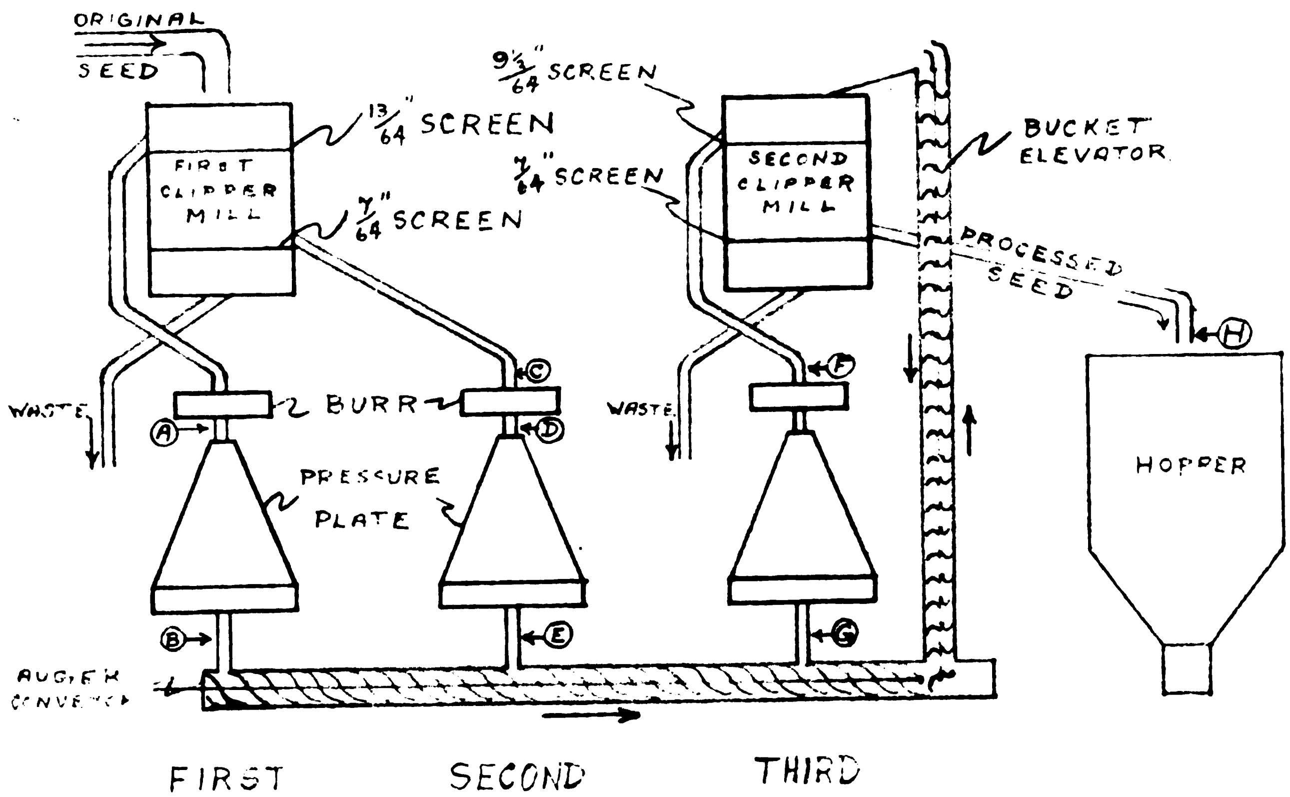
Seed between 7/64 inch and 13/64 inch in size passed into the second burr and pressure plate and then fed into the auger conveyor at D.

Material less than 7/64 inch in size fell through the lower screen and was discarded as waste.

The second clipper mill was fed from the auger conveyor by a bucket-type elevator, with material that had passed through the first and second burrs and pressure plates. This second mill also had two screens, the top one with a mesh of 9½/64 inch and the lower one with a mesh of 7/64 inch. Seed which passed through the first screen but remained on the second was led off into the processed seed hopper. Seed over 9½/64 inch in size passed down through the third burr and pressure plate into the auger conveyor and was returned to the top of the mill together with seed from the first and second burrs and pressure plates. Seed smaller than 7/64 inch in size dropped down through the lower screen and was discarded as waste.

Samples of seed were collected from the following locations:

DIAGRAM OF THE LAYOUT OF THE SUGAR BEET SEED PROCESSING PLANT



Location of Sample	Designation of Sample
A	Over 13 - After burr
B	Over 13 - After pressure plate
C	13-7 - Before treatment
D	13-7 - After burr
E	13-7 - After pressure plate
F	Over 9½ - Before treatment
G	Over 9½ - After pressure plate
H	Processed Seed (finished)

2) Analysis of Samples

Each sample of seed was sized over round-holed hand sieves, graded in 64ths of an inch, and fractions of each size in a sample were weighed. Counts were made to ascertain the number of seed-balls per pound. The results are given in Table II.

3) Discussion of the Results

In considering the effectiveness of the various stages in the processing of seed, it was obvious that the burrs did not do very much work. Table II shows that 24 percent of the original natural seed was graded off, larger than 13/64 inch, on the first clipper mill and passed into the first burr. Of the remaining 76 percent, 1.5 percent fell through the lower sieve as trash and the rest, from 7/64 to 13/64 inch, passed into the second burr. Table III shows the effect of burring on the material passing into the second burr.

TABLE II

Results of Grading Samples of Sugar Beet Seed Processed at Saginaw Plant

Size (64ths")	%	No. of Seeds in 2 gms.	No. of Seeds/lb.
Natural: 29,113 seed-balls/lb.			
13 and over	24.00	71	16,046
12 - 13	18.00	103	23,278
11 - 12	18.00	124	28.024
9½ - 11	25.00	153	34,578
9 - 9½	4.41	203	45,878
8 - 9	7.09	244	55,144
7 - 8	2.00	320 (1 sample)	72,320
Trash	1.50		
	100.00		
A. Over 13 - after Burr			
13 and over	4.34	70 (2 samples)	15,820
12 - 13	42.60	77	17,402
11 - 12	34.78	80	18,080
9½ - 11	8.70	110	24,860
8 - 9½)			
7 - 8)	2.60	275 (1 sample)	62,150
Trash	6.98		
	100.00		
B. Over 13 - after Pressure Plate			
13 and over	tr	-	-
12 - 13	tr	-	-
11 - 12	2.68	85 (1 sample)	19,210
9½ - 11	46.42	97	21,922
9 - 9½	10.08	122	27.572
8 - 9	13.13	156	35.256
7 - 8	3.57	325 (1 sample)	73,450
Trash	24.12		
	100.00		
C. 13 - 7 before treatment			
13 and over	1.04	93 (1 sample)	21,018
12 - 13	25.77	100	22,600
11 - 12	21.64	123	27,798
9½ - 11	34.02	155	35,030
9 - 9½	4.56	189	42.714
8 - 9	11.94	224	50,624
7 - 8	1.03	-	-
Trash	-		
	100.00		

TABLE II (Continued)

Size (64ths")	%	No. of Seeds in 2 gms.	No. of Seeds/lb
D. 13 - 7 after Burr			
12 and over	22.13	94	21,244
11 - 12	24.59	114	25,764
9½ - 11	36.89	152	34,352
8 - 9½	13.93	226	51,076
7 - 8	1.64	-	-
Trash	0.82	-	-
	100.00		
E. 13 - 7 after Pressure Plate			
11 and over	tr	-	-
9½ - 11	26.67	124	28,024
9 - 9½	13.03	153	34.578
8 - 9	28.00	189	42,714
7 - 8	14.36	273	61,698
Trash	17.95	-	-
F. Over 9½ - before treatment			
12 and over	tr	-	-
11 - 12	1.00	-	-
9½ - 11	98.00	106	23,956
8 - 9½	1.00	-	-
G. Over 9½ - after Pressure plate			
9½ and over	85.10	109	24,634
8 - 9½	9.42)		
7 - 8	0.53)	137	30,962
Trash	4.95		
H. Processed: 37,373 seed-balls/lb.			
9 - 9½	45.00	132	29,832
8 - 9	36.50	171	38.646
7 - 8	18.00	242	54,692
Trash	0.50	-	-
Monogerm			
	2 gms.	213	48,138

Of the 24 percent of seed over 13/64 inch that passed into the first burr, only 2.6 percent was reduced to the size of the processed seed and 46.94 percent remained on the 12/64 inch sieve - see Table II(A).

Table III shows that, of the 74.5 percent of seed between 7/64 and 13/64 inch that passed into the second burr, only the fraction which remained on the 12/64 inch was reduced, and then by only 4.6 percent.

TABLE III

Size (64ths")	% Before Burring	% After Burring
12 and over	26.81	22.13
11 - 12	21.64	24.59
9½ - 11	34.02	36.89
8 - 9½	16.50	13.93
7 - 8	2.68	1.64
Trash		0.82
	100.00	100.00

From these results it would appear that the function of the first and second burrs was merely to rub off some of the corners of the bigger seed-balls. As machines for reducing the size to less than 9½/64 inch, they were not very efficient.

The pressure plates showed much greater efficiency in reducing large seed-balls to the required size. The first reduced the 90.42 percent that is larger than 9½/64 inch in size. Almost one quarter of the weight of material going into this machine was discarded as trash.

The second pressure plate is equally as effective, for of the 83.61 percent of seed over $9\frac{1}{2}/64$ inch in size, all but 26.67 percent was reduced to the desired size. This machine discarded about 18 percent of the weight of intake as trash.

The results relating to the third pressure plate indicate that it was not set correctly, for of 98 percent of seed over $9\frac{1}{2}/64$ inch being fed into the machine only 12.9 percent was being reduced in size, the remaining 85.1 percent being returned via the auger conveyor to the mill for further treatment. This had a depressing effect on the output of the plant and was, in fact, the limiting factor to the quantity of natural seed that could be dealt with in a day.

It should also be noted that as processing progressed, seed density increased and the number of seed-balls in a given weight of a particular grade decreased, e.g. compare the 9/64 inch grade of natural seed with the same grade of processed seed. Seed density increased because much of the light corky husk had been removed in the process, thus giving a seed that would flow more regularly in planter units.

The recovery of finished seed was estimated by the plant operator to be somewhere in the region of 60 percent, by weight, of the natural seed fed into the hopper. This compares favorably with results given by Tingley (7) in which the average recovery from half a million pounds of natural seed was 60 percent with a peak recovery of 62.74 percent from 60,720 pounds of U. S. 15 seed.

GERMINATION

1) Germination Trial

Germination trials were carried out in the greenhouse on samples of seed processed at Saginaw. Twenty-five seed-balls of each grade were planted at one inch intervals in rows two inches apart in clean sand. The seed-balls were covered with a quarter of an inch of sand and watered alternately with water and nutrient solution.

Three replications were made so that in all, one hundred seed-balls of each grade were under observation.

Each replicate also included one row (25 seeds) of monogerm seed for comparison with the multigerm U.S. 400.

2) Results

Observations were made every day for fourteen days from the date of sowing in order to obtain a complete record of germination and the number of sprouts produced by each seed-ball. These results are summarized in Table IV.

TABLE IV

Results of the Germination of Various Grades of Sugar Beet Seed to show the Germination Capacity and the number of Sprouts produced per Seed-ball

Group	Size Over 64ths"	% of Seed-balls Giving 1,2,3,4, 5 or 6 Sprouts							Percent Germination
		None	1	2	3	4	5	6	
Natural	13	4	5	49	30	11	-	1	96
	12	4	12	60	23	1	-	-	96
	11	5	25	50	20	-	-	-	95
	9½	12	31	51	6	-	-	-	88
	9	24	28	42	6	-	-	-	76
	8	27	32	38	3	-	-	-	73
	7	44	31	25	-	-	-	-	56

TABLE IV (Continued)

Group	Size Over 64ths"	% of Seed-balls Giving 1,2,3,4, 5 or 6 Sprouts None	1	2	3	4	5	6	Percent Germination
Over 13	9	15	37	36	2	-	-	-	85
after Pres.	8	32	45	20	3	-	-	-	68
Plate	7	75	22	3	-	-	-	-	25
13 - 7	9	12	28	50	10	-	-	-	85
after	8	19	27	49	5	-	-	-	81
Pres. Plate	7	18	43	37	1	1	-	-	82
Processed	9	25	29	38	7	1	-	-	75
(9½ - 7)	8	12	33	53	2	-	-	-	88
	7	19	36	44	-	1	-	-	81
Monogerm		13	77	9	1	-	-	-	87

When these results are applied to the groups from which the grades were selected, i.e. natural, processed, over 13 after pressure plate, and 13-7 after pressure plate, they give the information compiled in Table V.

Unlike the seeds of other major farm crops, sugar beet seed can produce up to six or seven young plants and consequently the germination percentage by itself gives no true indication as to the number of plants that a sample of seed will produce. Table VI gives the number of seed-balls in each grade that will give one, two, three, or four sprouts. This information is further elaborated in Table VII when the numbers of multigerm seeds are expressed as percentages of the total number of seeds, and of the number of viable seeds in each group.

TABLE V

The Germination Capacity and Number of Seeds per Pound in both Grades and Groups

Group	Grade 1/64"	% of Grade in Group	No. of Seeds/lb.	No. of Seed-balls in 1 lb. of group	Germination % of Grade	No. of Seeds failing to Germinate	Germination %
Natural	13 & over	24.0	16,046	3,851	96	154	
	12-13	18.0	23,278	4,190	96	167	
	11-12	18.0	28,024	5,044	95	252	
	9½-11	25.0	34,578	8,644	88	1,037	
	9-9½	4.4	45,878	2,023	76	485	
	8-9	7.1	55,144	3,915	73	1,057	
	7-8	2.0	72,320	1,446	56	810	
				29,113		3,962	86.4
Processed	9 & over	45.0	29,832	13,424	75	3,356	
	8-9	36.5	38,646	14,105	88	1,692	
	7-8	18.0	54,692	9,844	81	1,870	
				37,373		6,918	81.5
Over 13 after Pres.Plate	9 & over	37.6	27,572	10,378	85	1,556	
	8-9	49.0	35,256	17,282	68	5,530	
	7-8	13.3	73,450	9,790	25	7,342	
				37,450		14,428	61.5
13 - 7 after Pres.Plate	9 & over	23.6	34,578	8,143	88	977	
	8-9	50.6	42,714	21,617	81	4,107	
	7-8	25.8	61,698	15,942	82	2,870	
				45,702		7,954	82.6
Monogerm				48,138	87	6,258	87.0

TABLE VI

The number of Seed-balls in each Grade that produce One, Two, Three or Four Sprouts

Grade	Germination %	Seeds per lb.	Viable Seeds/lb.	Sprouts per lb.	Sprouts/ 100 seeds	1 lb. of Seed gives: Singles	Doubles	Triples	Quad
Natural	86.40	29,113	25,145	48,211	165.6	6,870	13,940	3,867	465
Processed	81.49	37,373	30,455	50,515	135.2	12,110	16,907	1,221	232
Over 13 after P.P.	61.50	37,450	23,020	32,972	88.0	13,769	8,524	725	-
13 - 7 after P.P.	82.60	45,702	37,750	60,835	133.1	14,971	20,561	2,053	159
Monogerm	87.00	48,138	41,880	45,874	95.3	37,066	4,332	48	-

TABLE VII

Grade	% of Seeds that will give				% of Viable Seeds that will give			
	Singles	Doubles	Triples	Quads	Singles	Doubles	Triples	Quads
Natural	24.8	50.5	14.0	1.7	27.3	55.4	15.3	1.8
Processed	32.9	45.9	3.3	0.6	39.8	55.5	4.0	0.7
Monogerm	77.0	8.9	0.09	-	88.5	10.3	0.11	-
Over 13 after Pres. Plate	36.8	22.8	1.9	-	59.8	37.0	3.2	-
13 - 7 after Pres. Plate	32.8	45.0	4.5	0.3	39.7	54.5	5.4	0.4

3) Discussion of the Results

In discussing the germination of sugar beet seed, it must be realized that its value depends upon the characteristics that are desired. For instance, if high germination capacity is the primary objective the conclusions will be different to those drawn if the aim is to produce as many seeds as possible with only one germ.

Table IV indicates a germination percentage of 96.0 for natural seed that is over 13/64 inch in size, but the fact that 42 percent of this grade produces three or more sprouts per seed-ball makes it of doubtful use for current demands. Similarly, 88 percent of the seeds that germinate in the 7/64 - 8/64 inch grade of the "over 13 after pressure plate" group, produce single sprouts, but the germination is too low at 25 percent.

The germination of natural seed falls rapidly as it decreases in size until at 7/64 inch it is down to 56 percent. This agrees with the previously quoted findings of Price and Carsner (3).

Table IV also shows that although the first burr and pressure plate were very effective in reducing the number of multigerm seed-balls, the treatment was so harsh that the germination was severly affected, particularly with the smaller grades.

Germination was not appreciably affected by the second burr and pressure plate even though a considerable reduction was made in the number of seed-balls giving more than two sprouts.

In considering the groups from which the grades were selected, it was observed that there were 25 percent more seed-balls in one pound of processed seed than in the same weight of natural seed, due to the elimination of the coarser grades. Monogerm seed contained 65 percent more seed units per pound but had the same germination as natural seed.

Table VI shows that the number of sprouts per pound of seed actually increased slightly as a result of processing, the number of singles being doubled and the number of triples being reduced by two-thirds. When these results are expressed on a percentage basis, as in Table VII, the differences are not as great, for, whereas natural seed has a make-up of 75 single or double germ seeds in every 100 seed-balls, the processed seed has 79; and where natural seed has 25 percent of singles, processed seed has 32 percent.

When germination is taken into account, the highest number of singles in the viable seed is found, as might be expected, in the monogerm seed with the "over 13 after pressure plate" taking second place with almost 60 percent singles. Both the finished processed seed and the "13-7 after pressure plate" group contain 45 percent of double germ seed. Frakes (4) has shown that yields of sugar beets are not affected by leaving up to thirty percent of doubles in the crop, so, after allowing for thinning, it is reasonable to suppose that a seedling stand with 45 percent doubles will not appreciably reduce the yield of the crop.

CONCLUSIONS

The objects of processing sugar beet seed can be stated as follows:

1) To convert a seed that is variable in size, shape and germination capacity into something that is uniform in size, regular in shape and reliable in germination.

2) To obtain as high a degree of uniformity as possible in regard to the number of sprouts that a seed-ball will produce.

3) To reduce the number of sprouts per seed-ball to as low a number as possible without seriously impairing the germination.

4) To achieve the three previous aims with as high a degree of efficiency as possible, i.e. without excessive loss

of viable units.

Results obtained from processing and germinating sugar beet seed of variety U.S. 400 indicate that the processing plant of the Farmers and Manufacturers Beet Sugar Association at Saginaw was producing seed with the following characteristics:

1) It was between 7/64 inch and 9½/64 inch in size.

2) Less than 4 percent of the seed-balls gave three or more sprouts as compared to nearly 16 percent in natural seed.

3) The number of seed units giving single sprouts was 8.0 percent higher than in natural seed with a loss of only 4 percent in germination. Table VIII shows that by grading alone, the number of seed units giving single sprouts can be increased by 6 percent but as only 13.5 percent of natural seed falls into grades that are less than 9/64 inch in size, the losses involved in discarding the larger grades would be too great to warrant the adoption of such a practice.

TABLE VIII

The percentage of seeds producing single sprouts that remain after each grade is sieved off

% By Wt.	Remove Grade Larger Than	Natural	Over 13 After Pressure Plate	13-7 After Pres. Plate	Processed
24.0	13/64"	24.8			
18.0	12/64"	26.6			
18.0	11/64"	29.5			
25.0	9½/64"	30.9			
	(9/64"	30.7	36.8	32.8	32.4
13.5	(8/64"	31.7	36.7	33.8	34.2
	(7/64"	31.0	22.0	43.0	36.0

Similarly, if those seed units less than 8/64 inch in size from the "13 - 7 after pressure plate" group are used, 43 percent of singles can be obtained. However, as this grade amounts to only 14.3 percent of the group (see Table II), losses involved would be too great to justify its use.

Complete processing raises the number of singles from 24.8 to 32.4 percent and, with an estimated recovery of 60 percent, the numbers of multigerm seeds are reduced and single germ seeds increased without involving too great a loss in the process.

4) The efficiency of processing with a 60 percent recovery is comparable with the efficiency of other processing plants. In fact, if the number of viable seeds in a pound of processed seed is compared with the number of viable seeds in the natural seed needed to produce it (see Table VI), the recovery in terms of viable units is 72.6 percent e.g. from Table VI.

1 lb. of natural seed contains 25,145 viable units.
Recovery is estimated at 60 percent, therefore, 1 lb. natural seed gives 0.6 lb. of processed seed.
Since 1 lb. of processed seed contains 30,455 viable units, the number of viable units in seed processed from 1 lb. of natural seed is 30,455 x 0.6 or 18,273.
Therefore, the recovery of viable units equals $\frac{18,273}{25,145}$

or 72.67 percent.

PART II

PLANTING AND THINNING

The establishment of a sugar beet crop that will produce the maximum yield of roots and sugar per acre is the result of a number of individual but closely related operations.

Good viable seed must be planted in such a way that it will germinate evenly and in such a pattern that an optimum stand can be obtained with the minimum of hoeing and thinning.

The characteristic non-uniform field emergence of sugar beet seedlings is the result of three different elements in the sowing of the crop: (1) the lack of uniformity in soil moisture, soil temperature, etc., (2) the multigerm nature of natural seed and (3) the rough, casual method by which the seed is planted. Qualities involved in evaluating seed, such as size, viability, and the occurence of multigerm units are discussed elsewhere in this treatise. The method of sowing, however, has received very little consideration and, according to Andrews (8), there have been no major improvements for the precision planting of beet seed in the past thirty-five years.

The one exception to the lack of planter improvement has been the development of the Milton drill. This machine is a precision drill which will discharge seed evenly from seed cups traveling one inch above the bottom of the seed furrow.

When this method of seed delivery is compared with that of the conventional type of planter in which the seed bounces down two to three feet of seed tube and then rolls anywhere over four to five inches of seed furrow, the improvement will be obvious.

Other planters of the precision type have been recently introduced by other implement manufacturers.

The planting of seed and the subsequent mechanical operations necessary for the establishment of a good crop are very closely inter-related and present many complex problems to the agronomist and agricultural engineer.

The over-all problem in the establishment of an optimum stand of sugar beets is one of space relationships. Together, row width and the spacing of plants within the row, form the pattern in which plants are grown in the field. A great deal of research work and experimentation has been carried out to determine the ideal pattern or lay-out for optimum and maximum production.

REVIEW OF LITERATURE

Problems of space relationships in sugar beet crops have occupied the attentions of agronomists since the very beginnings of sugar beet culture. As farming techniques and practices have improved and developed, research work has increased and a vast amount of information is available on experiments that have been carried out in the United States, Great Britain and Europe.

The problem in sugar beets consists of a series of interlocking phases involving plant populations, field patterns, compensation for missing plants, and tolerance for multiple seedlings.

Plant Populations:

The results of research work are consistent in showing the value of high plant populations per acre. Doxtator (9) at Rocky Ford, Colorado, obtained the highest yields from populations of 25,000 to 35,000 plants per acre but pointed out that these were very difficult to obtain in 28 inch rows. The required 8 inch spacing caused the production of many small beets that were difficult to harvest and, when hand labor was used, probably involved a greater expenditure of labor and time than the increase in crop warranted.

Tolman (10 & 11) gives the standard recommended population in Utah as around 25,000 beets per acre and found in almost every case that yields decreased as the plant population was reduced below this figure.

Deming (12) states that with uniform distribution of plants, populations moderately in excess of the optimum of about 26,000 plants per acre will produce approximately a full crop of sugar beets.

Rayns (13) working in England gives the optimum population as 30,000 plants per acre.

However, it seems that as plant populations are increased beyond 30,000 per acre, there is a marked reduction in the size of individual roots which causes additional difficulties at harvest time.

<u>Row Width</u>:

The width of rows in which sugar beet should be planted has been the subject of extensive investigations. Tolman (11), Doxtator (9), Grey and Volk (14), Murphy and Carsner (15), Deming (16), and Skuderna (17) have all reported on this problem. The concensus of opinion seems to be that rows widely spaced cause a decrease in both the total weight of the beets harvested and in the percentage of sucrose, regardless of the total plant population.

Skuderna states that in the Red River Valley area of Minnesota where annual rainfall is less than twenty inches per annum, row widths greater than 22 inches caused a depression in beet yields and in sucrose percentage.

Doxtator (9) asserts that yields per acre of beets and sugar were highest in Colorado when planted in 20 inch rows at each of three population levels - 22,000, 26,000, and 30,000. This row width gave the highest yields for Deming (16) although the lowest yields from 22 inch and 24 inch rows were only 500 pounds, or less, of sugar per acre than the check so that convenience and savings in time may more than compensate for the reduction.

Grey and Volk (14) in trials with rows at 22, 28, and 36 inches wide, obtained the highest yields from the 22 inch width. Murphy and Eubanks (15) in comparing row widths varying from 22 to 44 inches, state that while rows wider than 22 inches may be desirable for harvesting operations, losses of up to six tons of beets per acre are incurred when the row width reaches 44 inches.

It is interesting to note that in spite of overwhelming evidence in favor of planting in narrow rows, the standard practice in Michigan is one of growing sugar beets in 28 inch rows because that width facilitates over-all farm operations. For example, 20 inch rows give 26,226 linear feet of row per acre to be hoed, thinned, cultivated, and harvested, as against only 18,668 linear feet from 28 inch rows.

Spacing:

The problem of the distance at which sugar beets should be spaced in the row is one that is not solved by dividing the intended plant population by the row width. Garner and Sanders (18) working in England on "Experiments in the Spacing of Sugar Beet," reported in 1939 and again in 1940 that wide row spacing could not be compensated by narrower spacing within the rows. They gave the minimum spacing as 9 inches.

Deming (12) working in Colorado obtained his highest yields from 20 inch rows with 100 plants to every one hundred feet of row and found that reductions in the stand below a uniformly distributed 100 resulted in a reduction in yield. These results were confirmed in the same year (1946) by Tolman (10) in Utah who went so far as to say that spacing closer than 12 inches was not beneficial regardless of row width, whether 20, 26, 32, or 38 inches. The results of further work on spacing by Tolman (11) agree with those of his earlier reports and he states that maximum yields are obtainable from 20 inch rows at 12 inch spacings.

Skuderna (7) reporting on experiments carried out in Minnesota from 1942-46 states that the highest yield was obtained from 15 inch spacings in 22 inch rows and that with wider rows, reduced spacing did not result in any improvement in yields.

In Michigan, Frakes (19) found that there was no significant difference from beets planted in 28 inch rows when spaced at 8, 10, 12, and 16 inches, but that there was a reduction in yield when spacing was reduced to six inches.

Gray and Volk (14) in Ohio reported in 1951 that in trials with spacings of 4, 8, 12, and 16 inches in rows 28 and 35 inches apart the 4 inch spacing gave the lowest yields. In comparing beets grown in rows 22 inches wide and spaced at 12 inches with beets grown in rows 36 inches wide and spaced at 6 inches, they obtained the highest yield from the narrower row width and wider spacing.

Reeve and Reeve (20) also working in Michigan, found that the highest yields of sugar per acre were obtained from 12 inch spacings.

Summing up, it would seem that spacial allotments which approach the square are more efficient than those that are extremely rectangular. Yields decrease progressively as the space allotment becomes more rectangular so that distorting the space allotment has more effect on yield than either increasing or decreasing it.

Multiple Occupancy:

The long-held conception of a perfect stand of sugar beets was of single plants spaced uniformly in rows of the optimum width. Yet as long ago as 1935, Brewbaker and Deming (21) stated that even if 25 percent of the stand was made up of doubles, root yields were not significantly lowered. They concluded that yields were determined by the pattern of plants and not by single plants. Deming (12) confirmed these results at Fort Collins, Colorado, and reported in 1946 that there was no difference in yield between 100 single-plant hills per 100 feet of row, and 100 hills with 25 percent doubles per 100 feet of row.

In comparing single plants spaced 10 inches apart with doubles thinned to 20 inches, Ryser and Owen (22) reported in 1946 that there was a small and possibly significant increase in yield from the single plants. However, they pointed out that if the difference was small with 100 percent doubles, it would be insignificant with the less than 100 percent doubles met with in ordinary field practice.

Frakes (19) in experiments with 0, 10, 20, and 30 percent doubles, found that the effect on the yield of roots and available sugar was not significant.

Additional evidence is given by Reeve and Reeve (20) who not only found that doubles had no effect on yield but state that the ideal stand of sugar beets is one which contains one hundred beet-containing blocks. more or less irregularly spaced, per 100 feet of row.

Compensation for Missing Plants:

There appears to be some divergence of opinion as to the effect of misses in a sugar beet stand. Brewbaker and Deming (21) in 1935 stated that eight beets surrounding a blank space in 20 by 12 inch spacing, were so increased in weight that there was a compensation of 96.2 percent of the loss due to a single missing beet. This view was confirmed in 1951 by Rayns (13) who stated that 86% of the loss in yield caused by a missing plant is compensated for by its neighbor.

However, Deming (23) working in Colorado reported in 1950 that additional plants present in multiple-plant hills may have some adverse effect on yields and that these plants in no way compensate for misses in the stand.

This review of literature covers only a small portion of the mass of experimental work that has been carried out on the space relationships of sugar beet.

As it appears now, it would seem that in so far as final yields are concerned, the particular row width or spacing is relatively unimportant. The important factor is more one of uniformity of stand, measured as beet-containing inches per hundred feet of row. Previously held notions that doubles are undesirable will have to be forgotten, the idea of achieving perfection by having plants spaced regularly at twelve-inch intervals will have to be replaced by an aim of having twelve beet-containing inches in twelve feet of row, and while row widths of thirty-eight and forty-four inches are far too wide for maximum yields the previously recommended optimum row width of twenty inches will have to be modified to allow for the efficient utilization of modern machinery.

FIELD OBSERVATIONS

The object of this study was to compare current practice in Michigan with the findings and recommendations of research work described in the foregoing review of literature.

The limited amount of time available prevented the execution of any critical trials but observations were made on a number of fields in Tuscola and Huron counties where precision drilling and space planting operations had been performed on a field scale.

Fields reported in these case studies had all been planted with seed of variety U.S. 400, processed to between 7/64 and 10/64 of an inch in diameter. Seed of this size contains approximately 37,400 seed-balls per pound and with a germination capacity of 81.5 percent is capable of producing 192,000 seedlings per acre when planted at a rate of four pounds per acre. According to results given in Part I of this treatise, this seeding could be expected to give approximately 49,216 singles, 64,250 doubles and 4,640 triples per acre. Planting was conducted in rows 28 inches wide so that in terms of hundred feet row lengths, the total number of possible plants would be 1,028, including 265 singles, 344 doubles and 25 triples.

Field 1.

Sugar beet seed was planted with a Palsgrove planter, embodying the Milton precision drill, at two different seed rates; viz, normal - at four pounds per acre, and space planting - with one seed every six inches at one pound per acre.

Observations made on April 28th gave the following information:

Normal Planting

Seed planted at four pounds per acre appeared to germinate more rapidly than space-planted seed. Counts showed an average of 771 plants per hundred feet of row in an even stand.

Space Planting

On germination, space-planted seed gave the following counts per hundred feet of row:

78 groups, including 24 multiples (30.7%), a total of 101 plants
66 groups, including 24 multiples (36.4%), a total of 90 plants
69 groups, including 27 multiples (34.8%), a total of 96 plants.

These figures give a mean of 71 groups, including 25 multiples (34.0%), to give a total of 96 plants.

Seed was planted at a rate of two hundred seeds per hundred feet of row so it would seem that germination was incomplete at the time that these counts were taken.

Further observations were made on May 20th and on this

occasion the number of plants in the space-planted rows averaged 132 beet-containing inches per hundred feet of row.

Counts were made of the number of gaps in the rows. These indicated that there was an average of seven gaps of up to three misses per hundred feet, and one gap of more than three misses (i.e. exceeding two feet) per hundred feet.

It was also observed that gaps were invariably followed by clusters of seedlings, two or three growing together, suggesting that either the drill had jumped or, that in some other way, seeds had been carried beyond the point at which they should have been planted.

Comments:

(1) Space planting on this field had been well done and the results looked impressive. The final count of 132 beet-containing inches per hundred feet of row was equivalent to a plant population of 24,600 per acre and as such was sufficient to give a good stand without further attention.

(2) The percentage of multiple seedlings, indicated by the first counts on April 28th, was in excess of the limits stated by Brewbaker and Deming (14), Deming (5), and Frakes (12), so that subsequent thinning or singling operations to remove some of the multiples would probably be beneficial to the ultimate yield of the crop.

Field 2.

This was a forty acre field, all but two acres of which has been planted with an International 4-row planter. The remaining area had been space-planted with a Palsgrove planter.

The International planted four pounds of seed per acre, equivalent to 750-800 seed-balls per hundred feet of row. The Palsgrove was set to plant one seed every six inches, or 200 seed-balls per hundred feet of row.

Observations made on April 28th gave the following information:

Normal Planting

Germination appeared to be complete. The resulting stand was even in growth but irregular in distribution and counts showed a variation of from 405 to 1,125 plants per hundred feet of row.

Space Planting

Counts gave the following information for hundred feet row lengths:

Units	Doubles	% Doubles	Total Plants
105	54	51.4	162
120	57	47.5	177

The large proportion of doubles in this field may have been due to soil conditions for the tilth was much more lumpy than that of Field 1. Bunching in the row could also have been caused by operating the planter at too fast a speed.

Further observations were made on May 20th when hired labor had completed thinning the crop, with disastrous results to the space-planted area of the field. Counts of hundred feet row lengths gave the following results:

								Mean
Plants	73	41	48	64	65	45	69	57.9
Doubles	2	-	5	4	1	2	4	2.57

It appeared obvious from the dead plants lying about that almost every double had been completely removed and only single plants had been allowed to remain.

Counts taken on that part of the field planted with four pounds of seed per acre gave an average of 73 plants per hundred feet of row, including eight doubles.

The thinning of the space-planted beets took seven minutes less for a seven hundred foot length of row (or about 3 hours per acre) than did the thinning of the normal seeding.

Comments:

(1) The recommended plant population for the district in which this field was located is 18,000 per acre. This is obtained in 28 inch rows by spacing at twelve inches, i.e. one hundred plants per hundred feet of row. With 73 plants per hundred feet of row the acre population is in the region of 13,600, and with 58 plants per hundred feet of row the population is only 10,700 plants per acre. According to Doxtator (9), Tolman (10 & 11), and Deming (12), both of these populations are too low.

(2) Prior to thinning, the stand of the space-planted area was high enough to give a population of at least 30,000 plants per acre so that the cause of a poor stand after thinning lies entirely with the operations of the hired labor.

(3) It is doubtful if the saving in time made in thinning space-planted seedlings was of sufficient magnitude to warrant the expenditure involved in purchasing a precision drill.

Field 3.

Space planting, with one pound of seed per acre, and normal planting, with four pounds of seed per acre, had both been carried out on this field.

Observations were made on May 20th after thinning operations had been completed. The following points were noted:

(1) Hired labor thinned the normal planting to 94 plants per hundred feet of row and had left 5 doubles.

(2) The farmer thinned the normal planting to 84 plants per hundred feet of row and had left 15 doubles.

(3) The farmer had thinned the space planting to 77 plants per hundred feet of row and had left 14 doubles.

(4) In the course of conversation the farmer expressed a preference for spacing greater than twelve inches and he believed that more generous spacing gave him a larger crop.

Comments:

(1) Hired labor did a better job of thinning than did the farmer in leaving a stand of approximately 18,000 plants per acre as against his of 15,000 or less. The 5.3 percent of doubles left by hired labor would have little or no detrimental effect on the ultimate yield.

(2) At the normal rate of planting the farmer left 17.7 percent of doubles, and with space planting he left 18.2 percent. This would suggest that with space planting at a rate of one pound of seed per acre there is rather less choice to the thinner in selecting single plants than there is with heavier planting rates. Even so, the percentage of doubles is well within the tolerances specified by Brewbaker and Deming (21), Deming (12), Frakes (19), and Reeve and Reeve (20).

(3) It is evident that the thinning standards to which the farmer was working were entirely different to those used by the labor. He preferred wide spacing and did not worry too much about doubles while they worked closely to twelve inch spacing and endeavored to leave only singles.

(4) The farmer reported a saving of 7 minutes per 700 feet of row in the space-planted beets, but objected to the increased bending that was necessary to obtain a stand of single plants.

Field 4.

This field had been planted with four pounds of processed seed per acre and at the time of the visit a four-row, differential-speed, down-the-row thinner was working in a good even stand of sugar beet seedlings. The plant population prior to thinning was estimated at 648 plants per hundred feet of row, or 121,000 per acre.

The mechanical thinner being used was of the "Dixie" type mounted in the "mid" position between the front and rear wheels of the tractor. The machine was geared so that the blades removed 3/4 inch of row eight times in every foot of travel when the tractor was driven in third gear.

The aim of the operation was to eliminate all hand labor except that required for a final trimming of the stand.

Counts were taken of the number of beet-containing inches remaining in one hundred feet of row after the tractor had been driven in first, second, and third gears.

Tractor Speed	Beet Inches/100 ft.	Estimated Plant Population
1st Gear	10	22,300
2nd Gear	17	37,000
3rd Gear	31	69,450

It was observed that unless the arms of the spinner hit the beet before they reached bottom dead-centre, the remaining plants were almost completely covered by soil. In some rows where this had happened it was practically impossible to locate the plants that had not been cut out.

A perfectly level field is essential for the efficient operation of the mechanical thinner for any irregularity in the form of back furrows causes the spinners to work at different depths, with disastrous results to the highest row.

Comments:

(1) Operation of this machine with the tractor in third gear reduced the stand by 50 percent to 69,450 plants per acre. Further thinning operations by machine or hand labor would be

necessary to obtain a satisfactory plant population. It was subsequently learned that the field was subjected to further machine thinning a few days later.

(2) Second gear operation resulted in a stand reduction of 70 percent to 37,000 plants per acre. Again, further thinning would be required to produce a satisfactory plant population.

(3) When the tractor traveled in first gear, 22,000 beet-containing inches were left per acre and this number would appear to be about right. However, it was felt by the operator that this treatment was too drastic and that a greater number of seedlings should be left.

(4) Plants not cut out were easily covered by soil and debris if the machine was not set and driven accurately. There appeared to be a very fine margin between leaving an uncovered stand and a smothered stand.

(5) The machine made no allowance for irregularities in the stand of seedlings. As it happened, germination in this field was very even but under less favorable conditions the machine could not differentiate between stands of high and low densities. The differential speed mechanism was easy to adjust but, as the adjustment could not be made from the driving seat, its use would require either an additional operator or stopping the tractor each time a variation in plant density gave need for an adjustment to the speed of the spinner.

(6) The thinner did an excellent job of removing weeds in the immediate proximity of the row, however, almost as good a

job would have been done by using a steerage tool-bar.

Field 5.

This was one of two fields visited in which an attempt had been made to obtain a satisfactory stand by planting one and a half pounds of seed per acre with a convential type of planter. This low seed rate was made possible by running the planter with small seed plates at a speed of 4 m.p.h.

Counts showed that the number of beet-containing inches per hundred feet of row varied from 49 to 68, and the number of gaps exceeding four feet in one hundred feet of row averaged out at eight.

Comments:

(1) Low seeding with a conventional planter resulted in the bunching of seed with large gaps between the bunches.

(2) Stand counts were too low to give satisfactory yields of sugar beet.

DISCUSSION

The problem of how to establish satisfactory stands of sugar beet with the minimum of labor requirements is being tackled from two different angles:

(1) By planting a reduced quantity of seed in such a way that each seed-ball is planted precisely at a specific distance from its neighbors on either side.

(2) By using machines, to replace hand labor, in thinning and gapping a normal stand of sugar beet seedlings to standards

which are much less exacting than those previously considered necessary for hand work.

Observations made in Michigan indicate that both methods are achieving a certain measure of success but neither provides the full answer and may not do so until monogerm seed becomes available for commercial use.

Under ideal conditions of soil and climate, the precision planter does a good job, but where soil conditions are not perfect it tends to bunch the seed, thus causing gaps and subsequent clusters of seedlings in the row.

Observations on Field 2 point to the need for close supervision of hired labor in the thinning of space-planted seed. Hired labor has been accustomed to leaving only single plants and chopping out doubles. In this case (Field 2), at least 50 percent of the stand was cut out leaving a plant population much too low for optimum yields. If labor cannot be trained to leave the proper number of plants, regardless of whether or not they are singles or doubles, the answer may lie in the precision planting of two pounds of seed per acre. The adoption of this latter method would mean that instead of obtaining 50 doubles and 50 singles in one hundred feet of row, from one pound of seed, the stand would consist of 100 doubles and 100 singles. With such a stand, the doubles could be chopped out and still leave 100 plants per hundred feet of row - but all singles.

The use of conventional type planters for low seedings was not successful and cannot be recommended. The construction

of the planter is such that seeds are bunched together in the row and gaps are left which are too large and too numerous to allow for the production of satisfactory yields.

The practice in Michigan of planting sugar beet in 28 inch rows and spacing to 14 or 15 inches produces, at best, a plant population of only 18,000 per acre. All the evidence of research work points to the advantages of narrower rows and a plant population of at least 25,000 per acre. It is difficult to understand why, especially on farms where the sugar beet is the main cash crop, this practice is continued. It would seem that the relationship of plant population and row width to yield is worthy of further study in the Michigan sugar beet area.

Visual results from the down-the-row thinner were less impressive than those from the precision planter. The stand remaining after the thinner had been once over the field was such that further gapping, either by hand or machine, was essential. The machine itself gave the impression of requiring a great amount of skill for correct setting and even then it made no allowances for either irregularities in the field surface or variations in the density of seedling stand. The differential speed adjustment, though ideal in conception, could not be operated from the driving seat of the tractor and even if that manipulation had been possible, it could not make allowances for variations in seedling density from row to row.

This machine is of definite value in controlling weeds adjacent to the row but the same effect could be obtained much less expensively by using a tractor-mounted steerage hoe.

In the absence of any experimental data on the subject it is difficult to place any value on the down-the-row thinner, for it would seem that hand labor in one operation could do a better job of thinning than three times over with the machine.

CONCLUSIONS

It can be concluded from the observations made in this study that neither precision planting nor mechanical thinning have yet been perfected.

Precision planting with a planter of the Milton type shows definite possibilities for the establishment of a satisfactory stand of sugar beets with little or no hand labor.

Until hired labor has been trained to leave beet-containing inches rather than single plants, it would seem advisable to use two pounds of seed per acre when planting with a precision drill. In this way, a sufficient number of single plants would be left to give a full plant population even if all doubles were chopped out.

The four-row down-the-row thinner is of some value when working with perfectly even stands of seedlings on level-surfaced fields. Under other conditions this type of machine is not satisfactory.

Future research work could be directed on making a comparison of the relative effectiveness in cost and yield between:

a) Sugar beets planted at four pounds per acre and thinned with a down-the-row thinner until a satisfactory stand is obtained; and

b) Sugar beet planted with a precision drill at two pounds per acre and thinned by hand labor.

PART III

HARVESTING EQUIPMENT

Attempts were made to design a machine that would top and lift sugar beets as far back as 1910, but it is only within the last decade that the mechanical harvesting of this crop has become a reality.

The first machines to appear in the Eastern area of the United States were two demonstrational John Deere harvesters. That was in 1942. In the following year, Michigan State College purchased a Scott-Urschel harvester and, by 1945, fifteen of these machines were operating in the area.

The shortage of suitable labor and consequent increase in its cost, gave added impetus to machinery designers and in 1946 Howard (24) quoted twenty different models that were either in production or in advanced stages of design in the United States. Since that time, the mechanization of the sugar beet harvest has proceeded rapidly until, in 1954, approximately 95 percent of the crop was lifted by machine. The growth of mechanical harvesting in the Eastern area is shown as follows:

Year	No. of Harvesters	% of Acreage Lifted By Harvesters
1942	2	
1943	1	
1944	4	

Year	No. of Harvesters	% of Acreage Lifted By Harvesters
1945	15	0.007
1946	180	6.2
1947	300	15
1948	440	30
1949	600	34
1950	800	51
1951	850	63
1952	850	77
1953	850	90
1940	900	95

(Growth compiled from references 25, 26, and 27)

Similar growth of mechanical harvesting has taken place in other beet-growing areas; e.g. there were 1,177 machines operating in California in 1951 (28), and in the same year, 77 percent of the beets grown in the Great Western area were lifted mechanically (29).

TYPES OF HARVESTER

Although twenty different types of machines were projected in 1946, only five weathered the storm of field experience and a brief description follows of those available in 1954.

1. McCormick H.M-1 Sugar Beet Harvester

Introduced by the International Harvester Company in 1946, the H.M-1 is a single-row tractor-mounted machine designed to lift 4-6 tons of beets per hour in a twenty tons per acre crop.

The beets are topped, while still in the ground, by a rotating notched disc. Uniform top removal is guaged by a

finder which is mounted ahead of the topping disc. The severed tops are thrown clear by a revolving finger top-flinger placed immediately behind the topping disc, and by adjusting the windrowing curtain it is possible to deposit the tops from four rows of beets into one windrow.

The lifting operation is performed by two lifting blades, or tines, and two notched rolling coulters. The coulters cut off trash and block off the ground on either side of the beet row. The blades catch the beets just below their maximum diameter and ease them up out of the ground. Both the depth of the lifting blades, and the width between them and the coulters, can be adjusted according to the demands of the crop.

Once lifted, the beets are delivered by guide rods to the cleaning trough where they are subjected to the action of thirty kickers mounted on four rotating shafts. As the beets come off the rear of the cleaning trough they are picked up by an elevator and passed to a trailing cart.

A sorting belt can be fitted to the cart so that if conditions are bad two pickers, standing on either side of the cart, can pick off the beets and allow soil and trash to pass over and be deposited on the ground.

The cart has a capacity of 1-1½ tons of beet. Unloading takes 1-2 minutes by an elevator running across the bottom of the cart and up to an adjacent truck.

2. <u>John Deere No. 100 Beet Harvester</u>

The John Deere is a comparatively new single-row machine introduced in 1953. The topping, lifting, and cleaning mechanisms are all mounted on the tractor and lead to an elevator which, in turn, leads directly into a trailing cart. The machine is designed to harvest 4-5 acres of sugar beet a day at a ground speed of $3\frac{1}{2}$ m.p.h.

The topping unit consists of two sets of finder wheels, one higher than the other, which are geared to the left front tractor wheel so as to rotate slightly faster than ground speed. This faster speed helps the finder wheels to climb over the beets and hold them back against the rigid knife.

Tops are removed by two spring-tooth wheels, mounted behind the knife and driven by the tractor power take-off. If the tops are required for feed, a simple ground-driven wheel can be fitted to throw the tops further out to the side.

Lifting is performed by two ground-driven wheels consisting of 22 steel tines. The shape of these wheels and the angle at which they work loosen the beets and lift them almost straight up without handling a lot of dirt. Cleaning discs keep the tines of the lifting wheel free of dirt and trash. Depth is controlled by a hydraulic lift.

When the beets are pushed out of the lifter they fall on to a long cleaning bed of 26 starwheels. Hold-down springs prevent the beets from passing over the cleaning bed too quickly. A loading elevator carries the crop from the cleaning bed to a revolving table on the trailing cart.

Under favorable conditions no hand sorting is deemed necessary but when hard clods are present they can be picked off by sorters and dropped down a shoot. The cart has a capacity of 1-3/4 tons and is emptied by an elevator in less than one minute.

3. Marbeet Sugar Beet Harvester

Constructed by the Blackwelder Manufacturing Company in California, the Marbeet is a tractor-mounted machine of original design. It requires only one operator.

Two adjustable coulters straddle the beet row and cut the soil on either side of the beet. They are followed by loosening ploughs which dig under the beet and raise them until they are impaled on the spikes of the pick-up wheel. Four feet in diameter, the pick-up wheel carries on its external surface four rows of closely spaced spikes which impale the beet by the crown and carry them round through 180 degrees to the topping discs. The cutting action of the coulters, the loosening action of the ploughs, and the pulling action of the wheel all help to clean the beets and eliminate the handling of large quantities of dirt and clods.

Topping is performed by two sharp rotating discs. As the pick-up wheel brings the beets into position, they are gradually lifted off the wheel by stripper blades extending between the rows of spikes. The rotating discs cut off the tops and the beets, flattened by a cross chain above the discs, pass on. The tops fall on to a high speed belt conveyor and are thrown well out beyond the tractor wheels.

In the meantime, the beets are tumbled and scrubbed by a spiral auger on to a chain belt conveyor which provides further cleaning action and carries them into a trailing cart.

Final cleaning action comes when the cart is emptied by the moving flights of the chain belt conveyor.

4. Scott - Urschel Sugar Beet Combine

The Scott Viner Company of Columbus, Ohio, manufactures three models of sugar beet harvesters. All are trailer type, have identical lifting mechanisms, and require two men to operate them. The differences lie in the topping mechanism and in the method of delivery of the beets. The three types of harvester are:

a) Stub - bar model

b) Rod model

c) Combination harvester and cart

Type c is, in effect, a Rod model in which the beets are delivered backwards into a mounted self-emptying cart. In the Stub-bar and Rod models the beets are delivered at the side into either a truck or a windrow.

The Scott - Urschel is a single row machine that first lifts and then tops the beets. It is steered into position on the beet row by an operator and the soil around the beets is broken by a plough. Two leaf pick-up points connected to the lower end of the lifter shoes slide over the ground and gather broken and dead leaves to prevent them from going into the load with the beets.

As the beets are loosened in the soil, the tops are gripped by the pick-up belts and conveyed to the topping mechanism. The pick-up belts are two rubber "V" belts pressed together by spring loaded idlers.

In the Stub-bar model, each beet is placed in position for topping by roller bars which can be adjusted to alter the level of topping. The original cost and maintenance of these roller bars was high so the Rod model was introduced in which the beets slide below guaging rods and are pulled down to the proper topping position.

The topped beets drop into the loading elevator and may be loaded directly into a truck or windrowed for later loading. The tops and crowns are discharged at the rear of the machine.

5. King - Wyse Sugar Beet Harvester

Manufactured by King-Wyse Incorporated of Archbold, Ohio, this machine lifts and loads two rows of beet at a time. Before it can be used, however, the tops must first be destroyed by a beater.

Lifting is performed by two power-driven wheels set at an acute angle to each other. The crown is removed by a fixed cutting edge and the beets are cleaned by a screen trough which deposits the crop on to a loading elevator for loading directly into a truck or laying in a windrow.

Power for the lifting, cleaning, and elevating mechanisms is provided by a 4-cylinder Wisconsin gasoline engine mounted on the frame of the machine. The hydraulic lift which con-

trols the raising and lowering of the lifting unit is operated by the hydraulic pump of the towing tractor.

PERFORMANCE OF HARVESTERS IN 1954

Observations were made during the 1954 lifting period on harvester performance in areas of three Michigan sugar factories, those of the Michigan Sugar Company at Saginaw and Sebewaing and the Monitor Sugar Company at Bay City.

The weather at harvest time was poor, 6.93 inches of rain falling in October and 2.11 inches in November. The average rainfall for the years 1946 - 1953 in the same areas was 1.85 inches for October and 2.29 inches for November (30). Consequently lifting conditions were difficult and this is reflected in the data collected from the factories, because all information was collected immediately after a period of rain.

The object of the investigation was to measure the efficiency of various harvesters as implements for lifting sugar beets, as distinct from the lifting of sugar beets, soil, and trash.

Before giving the results of these observations it is necessary to describe briefly the process by which beets are delivered at the factory.

On arrival, the truck loaded with beets, soil, trash and other extraneous matter is weighed. The load is tipped on to a beet piling machine which shakes off loose soil and trash (dirt) and collects it in a hopper for dumping in the truck after unloading has been completed. On leaving the factory, truck and dirt are weighed and by subtracting the second weight from the first the weight of unwashed beets is determined.

After passing over the cleaners on the piling machine, a sample of the beets is taken. These roots are brushed clean (corresponding to being washed) and any superfluous crown is removed. The weight of soil and crown taken from the sample is known as the "tare" and it is usually expressed as a percentage of the weight of clean, but unwashed, beets.

Records of tare weights were taken at all factories visited and are given in Table IX.

Additional information was collected at the Sebewaing plant in order to assess the weight of dirt which was being brought in with each load and then returned to the farm on the truck (Table X).

Not all the beets are processed on the day of their arrival at the factory. In fact, during the peak of the harvest season, at least 60 percent of the intake is piled into large storage heaps which measure 25 to 30 feet high, 50 feet wide, and up to 400 feet long. The storage of wet, muddy beets in large piles is accompanied by an increase in temperature which in turn increases the rate of respiration and causes heavy losses in sugar content. The beets in these piles are prevented from overheating by a ventilation system which is installed as the pile is built. Air is blown through ducts, made from old oil drums welded together, which run transversally across the pile at intervals of approximately twenty feet. Fan requirements are of the order of one 7½ horse-power fan for every 800 tons of beets.

Sugar beets come out of this short-term storage in remarkably good condition although excessive ventilation can cause dehydration of the roots. Much of the soil and dirt adhering to the beets at the time of piling dries out during storage and consequently when the roots are eventually taken into the factory for processing they are much cleaner than when they were piled.

DISCUSSION

In discussing the information compiled in Tables IX and X it is not intended to draw any conclusions of statistical value. For one thing, the number of samples is not large enough to make any accurate appraisal possible and secondly, too many other factors influence the harvesting of sugar beets to justify any critical examination. For instance, soil texture, drainage, method of loading (whether direct, from a trailer car, or from the windrow), and the skill of the operator, play a very important part in determining the amount of tare and dirt carried in each load. It is reasonable, however, to examine the trends portrayed and discuss them in relation to the machines involved.

Tare Percentages - Table IX

1. One of the most striking features of the information in Table IX is the wide variation, not only from farm to farm but for consecutive loads from the same farm. This confirms

TABLE IX

Tare Percentages of Sugar Beet Delivered at Three Michigan Sugar Factories

Machine	No. of Loads	Mean Tare %	Range	Field Conditions	Weather
John Deere	6	6.5	4 - 8	Light/sandy soil	Fine and dry
	10	11.8	8 -17	Medium loam	Fine after rain
	4	9.5	8 -11	Clay soil	Dry after rain
	20	9.26	Overall mean		
McCormick	8	9.4	4 -11	Heavy/ sticky	Fine and dry
	3	7.3	6 -10	Heavy/loam	Fine after rain
	3	7.0	5 -10	Clay soil	Fine after rain
	6	6.8	4 -10	Clay soil	Fine after rain
	20	7.63	Overall mean		
King-Wyse	9	9.7	7 -13	Light loam	Fine and dry
	14	6.6	2 -11	Light loam	Fine and dry
	9	12.0	6 -25	Medium loam sticky	Dry
	32	9.4	Overall mean		
Marbeet	5	11.4	8 -16	Medium loam wet patches	Fine after rain
	5	8.6	4 -13	Medium loam	Dry after rain
	5	18.2	8 -30	Clay soil	Fair after rain
	5	21.6	18 -28	Heavy/loam	Fair after rain
	4	13.6	9 -18	Heavy/loam	Fair after rain
	5	7.2	5 -10	Medium loam	Fair after rain
	29	13.4	Overall mean		

TABLE IX (Continued)

Machine	No. of Loads	Mean Tare %	Range	Field Conditions	Weather
Scott - Urschel	5	11.6	6 -17	Much soil	Fair after rain
	3	7.3	6 -10	Heavy/loam	Fair after rain
	5	8.4	6 -12	Clay soil	Fair after rain
	13	9.1	Overall mean		

TABLE X

Composition of Sugar Beet Loads

Beets from Field		Tare %	Composition of Load	
Gross Wt. lbs (Beets, dirt, tare)	Dirt % Screened off	Tare House	Tare-free Beets %	Dirt & Tare %
a) John Deere				
9,540	11.3	9	80.7	19.3
9.680	14.6	10	76.8	23.2
8,320	12.7	11	77.7	22.3
10,600	12.1	8	80.9	19.1
9,536	12.68	9.5	79.02	20.98
b) McCormick				
15,140	13.1	6	81.7	18.3
16,660	10.3	5	85.3	14.8
17,940	10.7	10	80.4	19.6
17,160	14.6	6	80.3	19.7
13,620	10.4	4	86.0	14.0
14,080	10.2	8	82.6	17.4
17,340	17.5	10	74.2	25.8
15,991	12.40	7.0	81.49	18.51
c) King-Wyse				
17,390	12.4	5	83.3	16.7
17,739	16.1	10	75.6	24.5
18,610	11.4	3	85.9	14.1
19,270	11.5	10	79.7	20.3
18,030	10.0	6	84.6	15.4
17,890	14.0	7	80.0	20.0
21,530	17.3	8	76.1	23.9
18,635	13.23	7.0	80.74	19.26
d) Scott-Urschel				
17,120	14.4	7	79.6	20.4
17,170	17.5	10	74.2	25.8
13,180	26.4	14	63.3	36.7
13,340	28.3	14	61.6	38.4
16,420	13.0	6	81.8	18.2
14,280	13.3	6	81.5	18.5
16,042	10.9	10	80.2	19.8
16,200	13.2	12	76.4	23.6
15,520	15.6	10	76.0	24.0
16,480	24.6	9	68.6	31.4
15,740	22.6	7	72.0	28.0
16,260	21.0	12	69.4	30.6
16,340	21.1	6	74.2	25.8
16,300	23.3	8	75.5	24.5
15,742	18.94	9.4	73.88	26.12

TABLE X (Continued)

Beets from Field		Tare %	Composition of Load	
Gross Wt. lbs (Beets, dirt, tare)	Dirt % Screened off	Tare House	Tare-free Beets %	Dirt & Tare %
e) Hand Lifting				
14,320	12.0	4	85.2	14.8
14,560	11.7	10	79.5	20.5
14,100	9.1	7	84.6	15.4
14,220	8.2	2	90.0	10.0
14,300	10.25	5.75	84.82	15.18

the view expressed previously that the machine is not the only factor involved in determining the cleanliness of the load. Consequently the efficiency of any machine should not be based solely on factory returns.

2. With the exception of the Marbeet, the mean tare percentages of all machines do not show much variation. After having seen the Marbeet working on soils of a heavy texture, it is easy to appreciate how so much tare is included in the load. The lifting action is such that, on soils of anything approaching a sticky nature, large quantities of adhering soil are pulled out of the ground with the beets.

The fact that the other machine which tops after the beets are lifted, the Scott - Urschel, does not give unduly high tare percentages may be due to better cleaning facilities on that machine.

Composition of beet loads as delivered to the factory - Table X

Although this table gives some very interesting information, the number of samples is too small to enable any accurate critical evaluation.

Nevertheless, the trend gives a useful indication as to the performance of various harvesters and this is particularly interesting when a comparison is made with four loads that were picked by hand.

Again, it will be observed that there is a wide diversification between loads harvested by the same machine in the same field. It is worth noting that this diversification is even more pronounced in the case of beets lifted by hand.

Although the percentage of tare in loads harvested by the Scott - Urschel is normal, it will be observed that the percentage of dirt is abnormally high. The lifting mechanism of this machine is such that no selection is made between weeds and beets and consequently everything growing between the pick-up tines is lifted and passed back into the truck or trailer. Unless the field is weed-free, considerable quantities of trash, leaves, and fibrous roots are mixed in the load.

The real significance of the high dirt and tare content of loads harvested by the Scott - Urschel can be more fully realized when they are compared with loads picked by hand. For instance; a forty acre field of sugar beets yielding 15 tons per acre would require 101 journeys by a truck carrying 16,000 pounds if the crop were lifted by a Scott - Urschel. The same field, if harvested by hand would have required only 88 journeys.

Obviously the question to be answered is whether or not the saving of 13 journeys will justify the additional cost of using hand labor, a question which only the farmer himself can answer.

There would appear to be very little to choose from regarding the other three machines, although the data indicates that the McCormick is somewhat superior to the John Deere in its ability to harvest clean beets.

CONCLUSIONS

A brief outline has been given of the development of mechanical sugar beet harvesting and the machines available in 1954 have been described.

Data collected at three Michigan sugar factories during the 1954 harvest period has been presented and on analysis the following conclusions have been drawn:

(1) The harvester is not the only factor involved in accounting for the tare and dirt present in loads of sugar beets as they are delivered to the factory.

(2) With the exception of the Marbeet, there is very little difference in the cleaning efficiency of sugar beet harvesters in so far as the percentage of tare recorded in 1954 is concerned. It should be remembered that weather conditions during the harvest period were not of the best.

(3) Dirt percentage figures indicate that the Scott - Urschel is not sufficiently selective in the material that it harvests.

(4) Hand lifting gives a cleaner sample both as regards dirt and tare, so that where cleanliness assumes economic significance, and hand labor is available, it may be more profitable to harvest the crop manually. The use of hand labor may, on the other hand, involve problems of labor management. In the case of seasonal gang labor, these problems could cause a greater expenditure of time and patience than would be justified by the savings brought about through transporting and delivering a clean crop.

GENERAL SUMMARY

The aim, or goal, of all concerned in the growing of sugar beets is to reduce peak seasonal labor requirements to a point where the crop can be planted, thinned, cultivated, and harvested by the normal farm labor staff. Seasonal labor is erratic, undependable, and costly, consequently developments in sugar beet cultivation have been directed to methods by which the farmer can become independent of outside help, with the exception of help on a "custom" basis from other farmers who have expensive machines for which they require more hours of work.

Assuming that single spaced plants are necessary or highly desirable, it seemed a logical step to process beet seed in an effort to get a seed that approached the single germ condition. By the processing system described in Part I, a satisfactory seed was obtained with a loss of only 28 percent of the viable units and an increase of 30 percent in the number of singles. It is hoped that before long a satisfactory variety of monogerm seed will be available for commercial use. With the general adoption of this type of seed, processing will become obsolete.

With the ideal of single-germ seed "just around the corner," developments are taking place in the design and operation of planting devices. Machines are becoming available that will space-plant seeds precisely at pre-set intervals in a soil micro-climate conducive to prompt and uniform germination. Such machines are expensive and unless conditions are ideal, they are of doubtful value at the present time. However, the day is not far distant when, by using a combination of precision planting and appropriate weedicides, all hand labor will be eliminated in the establishment of a crop.

The concept that doubles are not especially harmful when mechanical harvesting methods are used, has given great impetus to the development of mechanical thinning devices. With beet plants being found in a given number of individual inches in every one hundred inches, a machine that removes every other inch will obviously reduce the stand by half. Thus by considering the number of beet-containing inches, a mechanical thinner can be set to work accurately in a uniform stand. Lack of uniformity within and between the rows obviously leads to difficulties when a four-row machine is used. Such a machine requires very accurate adjustment and will only work satisfactorily on a perfectly level seed-bed worked to a fine tilth. Nevertheless, progressive farmers in greater and greater numbers are finding it possible to use these machines. The value of mechanical thinning devices would appear to be high in seasons when weather conditions encourage a rapid germination of both beets and weeds. In such a case, the down-the-row thinner can often cut the labor requirements to a point where hand-trimming is economically possible. As with processed seed, thinning machines may well become obsolete within a few years if a satisfactory variety of monogerm seed is introduced. However, in the meantime their use has a definite place on the farms of careful, progressive farmers.

Mechanization at the other peak of labor requirement, the harvest period, has almost been completed. This is not to say that the machines being used are without possibilities of improvement, but they have been developed to a stage where they will harvest beets from soil that is either dry or very wet. The fact that these machines load a good deal of soil and other "tare" into the truck is considered unfortunate. Actually the dirt content is only a matter of degree since beets are inevitably in need of washing before they can be processed. Furthermore, the soil, in general, is considered only as occupying space that would otherwise be occupied by air. Loads are somewhat heavier than they would be if the beets were clean but as most of the growers deliver their crop in their own trucks, this is an almost negligible item. There are several makes of machines on the market that are generally comparable in their efficiency.

Vigorous experimentation, therefore, is being continued by all levels of interest, the farmer, the manufacturer, the sugar companies, and the State and Federal experiment stations, in an attempt to "keep one jump ahead" of actual present possibilities in the mechanization of the sugar beet crop.

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