METHODS OF TESTING MOTHER BEETS FOR SUGAR CONTENT

THESIS FOR DEGREE OF M. AGR.

ELDON E. DOWN

1922

Beets + beet pulp.

METHODS OF TESTING MOTHER BEETS

FOR SUGAR CONTENT

METHODS OF TESTING MOTHER BEETS

FOR SUGAR CONTENT

Thesis

Respectfully submitted in fulfillment for

the degree of Master of Agriculture

at

Michigan Agricultural College

M. Agr.

Eldon A. Down

1922

THESIS

-TABLE OF CONTENTS-

Page

Page

I--INTRODUCTION

(1). Need of Investigation.

The Michigan sugar beet industry depended on foreign seed before the World War. A sudden reduction of the quantity and quality of the supply forced the sugar manufacturers to grow their own. At present, some have returned to the foreign source, while others are growing at least a part of their seed. About 250 acres of beets for seed will be grown in Michigan during the summer of 1922. Tests at the Michigan Agricultural College during 1921 showed that the Michigan grown seed produced a greater tonnage of beets per acre, but with a lower sugar test than foreign grown seed. These results are borne out by the earlier work done under the direction of Director Smith of the Michigan Agricultural College Experiment Station and by the observations of the manufacturers. The lower sugar content is no doubt due to the correlation between size of beet and sugar content, while the increase in tonnage may be due to the seed becoming adapted to Michigan conditions. However, this decrease in the percent sugar makes it less profitable to extract sugar from beets produced from Michigan grown seed. Because of this condition, investigation should be undertaken that will aid in the selection of a type of beet that will give a reasonable tonnage under Michigan conditions and have a high sugar content.

It is not known how the inheritance for sugar content is transmitted from a mother beet to its off-spring; it can only be compared to other open pollinated crops. An individual beet is the resultant of two forces: heredity and environment. These are so related that it is impossible to tell which is the more important. Heredity determines what type an individual should be, while environment determines whether the individual will develop to the limit set by its heredity or not. No matter how good the environment may be, the individual can not develop beyond this limit. Because the ultimate yielding power of any variety is limited by the hereditary yielding power of the original stock from which it came, it is most important that this stock be the best that can be obtained. It is the purpose of this thesis to discuss methods of testing mother beets for sugar content to determine those best suited to become the foundation stock of future varieties.

(2.) Methods Under Discussion, Defined.

Three general methods of testing mother beets for sugar content are discussed: chemical, specific gravity,

and genetic.

The chemical method is a process of determining the percent of sugar in a beet by analyzing a core sample.

The specific gravity method is a process of determining the percent sugar in a beet by immersing the whole beet in a solution of given specific gravity.

The genetic method is a process of determining the hereditable percent sugar of a beet by its progeny record.

II--CHEMICAL METHOD

(1.) Selecting Beets in the Field.

Mother beets are carefully selected in the field, chiefly on the basis of leaf surface and size of beets. Characters such as: large leaf surface, leaves with fine texture, wrinkled leaves, roots having many fine rootlets, and deep root furrows, are also considered. These points are selected because there is some data to show that a positive correlation between them and sugar content exists. Also, there is a general belief that these characters are transmitted to their progeny. The selected beets are stored under uniform conditions until the following spring.

(2) Testing for Sugar Content.

The final selection is based on the percentage of sugar found in the root. The method of obtaining a sample of the mother beet for sugar analysis used by the different breeders is essentially the same. The sample for analysis is obtained by boring a hole diagonally through the thickest part of the beet in such a way as to sample all the zones of high and low sugar. The sugar is extracted from a given weight of pulp by any one of a number of standard methods. The solution containing the sugar is then placed in a tube which is inserted in a saccharimeter and the percent sugar read direct. The beets with the highest sugar test are thrown into a superelite class and used for further breeding. Those above the average are classed as elite and used for increase seed production; the remainder are discarded.

The ability of the superelite class to transmit high sugar content to its progeny will be discussed under the genetic methods.

III--SPECIFIC GRAVITY METHODS

(1.) Previous Investigation.

Breeders have for many years separated beets with a high and low average sugar content by floating off the low average group on a solution of a given specific gravity.

It is not known how long this has been done. Fruwirth in his book "Die Züchtung Der Landwirtschaftlichen Kulturpflanzen", refers to the early breeders determining percent sugar by floating slices of beets on a standard sugar solution. Wares in his book "Sugar Beet Seed", tells of the German breeders using a salt solution to make a preliminary separation of breeding beets into high and low average sugar content before the chemical analysis is made. Harris in his book "Sugar Beets in America", mentions the method. However, no data is given by these authorities to show that there is a definite relationship between the specific gravity and sugar content.

Work reported by M. Rene Pique, chemist at Arras, France, shows that the average sugar content increases with the increase of the specific gravity.

(2). Present Investigation.

The writer undertook an investigation that would determine whether the relationship between the specific gravity and sugar content of Michigan grown beets is sufficient to allow for their separation into groups with high and low average sugar content by means of a salt solution.

A. Source of Material.

The beets used in this investigation were taken from the varietal tests conducted by the Farm Crops Department during the summer of 1921. Only those beets that appeared healthy and reasonably free from leaf spot (Cercospora beticola) were selected with the exception of 27 badly diseased (leaf spot) ones that were chosen to determine the maximum effect of this disease. Later it was found that part of the healthy beets had hollow crowns. This allowed the beets to be classified into three groups: healthy, diseased (not hollow), and hollow.

B. Determination of Specific Gravity.

The specific gravity of 391 beets was obtained by the usual method of determining the density of a body heavier than water. The beets were first weighed in air and again while immersed in distilled water. The quotient obtained by dividing the weight of a beet in air by the difference between the weight in air and in distilled water is called the calculated specific gravity in this thesis.

To determine the specific gravity by salt solution, 279 beets were immersed in a salt solution with a density of 1.045. A solution of 1.045 was used because it is known that the specific gravity of beets

Source of material used
in specific gravity investigation.

Equipment used in determining specific gravity of the beet.

range from 1.005 to 1.090. The beets that floated were assumed to have a specific gravity less than 1.045, while those that sank were considered to have a greater specific gravity. Since the former group contained beets from 1.005 to 1.045 and the latter group ranged from 1.045 to 1.090, the midclasses used for each group were 1.025 and 1.065 respectively.

C. Determination of Sugar Content.

All sugar analyses were made by the Experiment Station, Chemistry Division of the Michigan Agricultural College, under the direction of O. B. Winter. Each beet was ground and a uniform sample of its pulp used for sugar extraction purposes. The hot water digestion method of analysis was used.

(3.) Relationships (Correlations): Whole Beets.

The method of calculating the coefficient of correlation and probable error is that explained by Eugene Davenport in his "Principles of Breeding", pp.419-492. If there is a perfect correlation in two characters the coefficient is unity, while if there is no correlation the coefficient is zero. If the coefficient is not greater than four times its probable error it is usually considered not significant. When the correlation is negative the coefficient is preceded by a minus sign. The coefficient of correlation between the different

factors are shown in the following tables.

Besides the correlation between specific gravity and sugar content, the relationship between factors that may influence this relationship were determined.

A. Specific Gravity vs. Sugar Content.

(a) Healthy Beets.

1. Specific Gravity Calculated.

Table 1 shows the results for 310 beets. A positive correlation of .5401 is shown between specific gravity and sugar content with a probable error of .0271. This correlation is definite and is usually expressed as follows: .5401 $\pm$ .0271.

-Table 1-

Correlation between specific gravity and sugar content.

Healthy Beets.

X--	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	
10			4						4
11		5	9	3					17
12		3	13	16	1	1			34
13		1	13	30	12				56
14	1		8	44	19	3			75
15		2	7	15	21	4	1		50
16	1	1	3	6	21	12			44
17			2	4	11	8	1		26
18				1			1	1	3
19					1				1
Y									Total
	2	12	59	119	86	28	3	1	310

X = midclasses for specific gravity (calculated).

Y = midclasses for sugar percent.

Correlation = .5401 ±.0271.

Mean specific gravity = 1.0471.

Mean sugar percent = 14.1387.

2. Specific Gravity by Salt Solution.

An examination of table 2 shows a positive co-relation of .5873 ± .0291 between the specific gravity of 231 beets and their sugar content. The coefficient is over 20 times its probable error.

-Table 2-

Correlation between specific gravity (salt solution) and sugar content. Healthy beets.

X	1.025	1.065	
10	3		3
11	12	2	14
12	18	5	23
13	17	15	32
14	18	31	49
15	7	33	40
16	2	39	41
17		25	25
18		3	3
19		1	1
Y	77	154	Total 231

X = midclasses for specific gravity.

Y = midclasses for sugar percent.

Correlation = .5873 ± .0291.

Mean specific gravity =1.0516.

Mean sugar percent = 14.3549.

(b) Healthy and Diseased Beets (not hollow).

1. Specific Gravity Calculated.

Table 3 gives results with 337 beets, and shows a correlation of .6898 ± .0192. The coefficient is over 35 times its probable error.

-Table 3-

Correlation between specific gravity (calculated) and sugar content. Healthy and diseased beets (not hollow).

X--	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	
1		1								1
2										
3										
4			1							1
5		1								1
6	1									1
7	2	3								5
8	1	1	1							3
9										
10		3	2	5						10
11			8	9	3					20
12			6	14	16	1	1			38
13		1	2	13	30	12				58
14		1		8	44	19	3			75
15			2	7	15	21	4	1		50
16		1	1	3	6	21	12			44
17				2	4	11	8	1		26
18					1			1	1	3
19						1				1
Y	4	12	23	61	119	86	28	3	1	Total 337

X = midclasses for specific gravity (calculated).

Y = midclasses for sugar percent.

Correlation = .6898 ± .0192.

Mean specific gravity = 1.0448.

Mean sugar percent = 13.7211.

2. Specific Gravity by Salt Solution.

Table 4 shows the results with 255 beets. A positive correlation of .6241 ± .0258. The coefficient is practically 25 times it probable error.

-Table 4-

Correlation between specific gravity (salt solution) and sugar content. Healthy and diseased beets (not hollow).

X-	1.025	1.065	
2	1		1
4	1		1
5	1		1
6	1		1
7	4		4
8	3		3
10	8		8
11	14	2	16
12	22	5	27
13	19	15	34
14	18	31	49
15	6	33	39
16	2	39	41
17		25	25
18		3	3
19		1	1
Y	101	154	Total 255

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .6241 ± .0257.

Mean specific gravity = 1.0491.

Mean sugar percent = 13.8471.

(c) Healthy, Diseased and Hollow Beets.

1. Specific Gravity Calculated.

Table 5 shows a correlation of .6870 ± .0180 between the calculated specific gravity and sugar content. The correlation is definite.

-Table 5-

Correlation between specific gravity (calculated) and sugar content. Healthy, diseased and hollow beets.

X--	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	Total
1		1								1
4			1							1
5		1								1
6	1									1
7	2	3								5
8	1	1	1							3
9			1							1
10		3	3	5						11
11			8	13	4					25
12			10	19	20	1	1			51
13		1	5	14	34	13				67
14		1		14	50	21	3			89
15			2	8	18	23	5	1		57
16		1	1	3	6	24	13			48
17				2	4	11	8	1		26
18					1			1	1	3
19						1				1
Y	4	12	32	78	137	94	30	3	1	391

X = midclasses for specific gravity.

Y = midclasses for sugar percent.

Correlation = .6870 ± .0180.

Mean specific gravity = 1.0443.

Mean sugar percent = 13.6471.

2. Specific Gravity by Salt Solution.

Table 6 shows the correlation between the specific gravity (salt solution) and sugar content to be .6161 ± .0251. The coefficient is over 24 times its probable error.

-Table 6-

Correlation between specific gravity (salt solution) and sugar content. Healthy, diseased and hollow beets.

X--	1.025	1.065	
2	1		1
3			
4	1		1
5	1		1
6	1		1
7	4		4
8	3		3
9	1		1
10	9		9
11	16	2	18
12	26	5	31
13	22	15	37
14	23	32	55
15	10	34	44
16	2	42	44
17		25	25
18		3	3
19		1	1
Y			Total
	120	159	279

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .6161 ± .0251.

Mean specific gravity = 1.0477

Mean sugar percent = 13.8028.

B. Specific Gravity vs. Weight.

(a). Healthy Beets.

1. Specific Gravity Calculated.

Table 7 shows the correlation between the specific gravity (calculated) and weight to be -.1015 ± .0379. The correlation is not significant. The coefficient is less than 3 times its probable error.

-Table 7-

Correlation between specific gravity and weight. Healthy beets.

X--	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	
100	1	2	6	8	7	4			28
200		4	12	26	26	9	2	1	80
300	1	3	9	19	13	8	1		54
400		1	6	19	21	1			48
500		2	5	14	5	3			29
600			9	14	6	1			30
700			7	7	3	1			18
800			1	6	4				11
900			4	3		1			7
1000				1					1
1200					1				1
1300				2					2
Y	2	12	59	119	86	28	3	1	Total 310

X = midclasses specific gravity. Mean specific gravity = 1.0471.

Y = midclasses weight in grams. Mean weight in grams = 387.4194

Correlation = -.1015 ± .0379.

2. Specific Gravity by Salt Solution.

Table 8 shows there is a slight correlation between the specific gravity (salt solution) and weight of beet. The correlation is -.2221 ± .0422. The coefficient is over 5 times its probable error.

-Table 8-

Correlation between specific gravity (salt solution) and weight.

Healthy beets.

X	1.025	1.065	
100	5	23	28
200	20	50	70
300	11	26	37
400	9	22	31
500	8	10	18
600	8	10	18
700	7	7	14
800	5	2	7
900	3	3	6
1000		1	1
1300	1		1
Y			Total
	77	154	231

X = midclasses specific gravity. Mean specific gravity = 1.0516.

Y = midclasses weight in grams. Mean weight in grams = 360.1731.

Correlation = -.2221 ± .0422.

(b) Healthy and Diseased Beets (not hollow).

1. Specific Gravity Calculated.

Table 9 shows that the addition of the diseased beets decreases the correlation. The coefficient of correlation is -.0245 ± .0367. The correlation is zero. The probable error is greater than the coefficient.

-Table 9-

Correlation between specific gravity (calculated) and weight.
Healthy and diseased beets (not hollow).

X--	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	
100		3	5	6	8	7	4	2	1	36
200	2	1	8	12	26	26	9	1		85
300	2	6	6	9	19	13	8			63
400			1	6	19	21	1			48
500		2	2	6	14	5	3			32
600				9	14	6	1			30
700				7	7	3	1			18
800				1	6	4				11
900				4	3		1			8
1000					1					1
1100			1							1
1200						1				1
1300				1	2					3
Y	4	12	23	61	119	86	28	3	1	Total 337

X = midclasses specific gravity. Mean specific gravity = 1.0448.

Y = midclasses weight in grams. Mean weight in grams = 381.3056.

Correlation = -.0245 ± .0367.

2. Specific Gravity by Salt Solution.

Table 10 shows that the correlation between the specific gravity (salt solution) and weight was also decreased with the addition of diseased beets. The correlation is $-.1689 \pm .0410$.

-Table 10-

Correlation between specific gravity (salt solution) and weight.

Healthy and Diseased beets.

X--	1.025	1.065	
100	10	23	33
200	27	50	77
300	19	26	45
400	9	22	31
500	10	10	20
600	8	10	18
700	7	7	14
800	5	2	7
900	3	3	6
1000		1	1
1200	1		1
1300	2		2
Y			Total
	101	154	255

X = midclasses specific gravity. Mean specific gravity = 1.0491.

Y = midclasses weight in grams. Mean weight in grams = 356.8627.

Correlation = $-.1689 \pm .0410$.

(c). Healthy, Diseased and Hollow Beets.

1. Specific Gravity Calculated.

Table 11 shows that the correlation is increased by the addition of the hollow beets. The coefficient is -.1044 ± .0337. The coefficient is slightly over 3 times its probable error.

-Table 11-

Correlation between specific gravity (calculated) and weight.

Healthy, Diseased and Hollow beets.

Y \ X	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	Total
100		3	5	6	8	7	4	2	1	36
200	2	1	8	13	27	28	9	1		89
300	2	6	8	10	21	14	10			71
400			1	12	24	22	1			60
500		2	2	9	22	6	3			44
600			1	12	16	8	1			38
700			1	8	7	4	1			21
800			2	2	6	4				14
900				4	3		1			8
1000					1					1
1100			1	1						2
1200						1				1
1300			1	1	2					4
1400			1							1
1500			1							1
Total	4	12	32	78	137	94	30	3	1	391

X = midclasses specific gravity. Mean specific gravity = 1.0443.
Y = midclasses weight in grams. Mean weight in grams = 401.7903.

Correlation = -.1044 ± .0337.

2. Specific Gravity by Salt Solution.

Table 12 also shows an increase in the correlation with the addition of hollow beets. The correlation is -.1841 ± .0390.

-Table 12-

Correlation between specific gravity (salt solution) and weight. Healthy, Diseased and Hollow beets.

X--	1.025	1.065	
100	10	23	33
200	30	51	81
300	23	28	51
400	12	22	34
500	14	11	25
600	10	11	21
700	8	7	15
800	7	2	9
900	3	3	6
1000		1	1
1200	1		1
1300	2		2
Y			Total
	120	159	279

X = midclasses specific gravity. Mean specific gravity = 1.0478.

Y = midclasses weight in grams. Mean weight in grams = 363.4408.

Correlation = -.1841 ± .0390.

C. Sugar Content vs. Weight.

(a). Healthy Beets.

Table 13 shows the relationship between sugar content and weight to be -.4552 ± .0304. The coefficient is 15 times its probable error.

-Table 13-

Relationship between sugar content and weight. Healthy beets.

Y \ X	100	200	300	400	500	600	700	800	900	1000	1200	1300	Total
10						1	1	1	1				4
11		3	7	1	3	1	2						17
12	1	5	4	5	3	8	1	3	2	1		1	34
13		8	8	10	6	10	6	2	4		1	1	56
14	5	14	9	19	11	7	5	5					75
15	6	15	10	10	5	2	1		1				50
16	9	20	12	2	1	1	1						46
17	6	14	4				1						25
18		1	1										2
19	1												1
	28	80	55	47	29	30	18	11	8	1	1	2	310

X = midclasses weight in grams.

Y = midclasses sugar percent.

Correlation = -.4552 ± .0304.

Mean weight in grams = 387.0967.

Mean sugar percent = 14.1258.

(b). Healthy and Diseased Beets (not hollow).

Table 14 shows that the addition of the diseased beets has materially reduced the correlation. The correlation is -.2792 ± .0338.

-Table 14-

Correlation between sugar content and weight. Healthy and diseased beets (not hollow).

Y \ X	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	Total
2		1												1
4											1			1
5					1									1
6			1											1
7		3	2											5
8		1	2											3
10	1		3		1	1	1	1	1					9
11		5	7	1	4	1	2							20
12	3	6	6	5	3	8	1	3	2	1			1	39
13	2	8	8	10	6	10	6	2	4			1	1	58
14	5	14	9	19	11	7	5	5						75
15	6	15	10	10	5	2	1		1					50
16	9	20	12	2	1	1	1							46
17	6	14	4				1							25
18		1	1											2
19	1													1
Y	33	88	65	47	32	30	18	11	8	1	1	1	2	337

X = midclasses weight in grams. Mean weight in grams = 378.9317.

Y = midclasses sugar percent. Mean sugar percent = 13.7210.

Correlation = -.2792 ± .0338.

(c). Healthy, Diseased and Hollow beets.

Table 15 shows the correlation has slightly increased with the addition of the hollow beets. The coefficient of correlation is -.3044 ± .0395. The coefficient is about 7.5 times its probable error.

-Table 15-

Correlation between sugar content and weight.

Healthy, Diseased and Hollow beets.

X	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	Total
2		1												1
4										1				1
5					1									1
6			1											1
7		3	2											5
8		1	2											3
9								1						1
10	1		3		1	2	2	1	1					11
11		5	8	2	6	5	3	1						30
12	3	6	6	7	6	8	1	4	2	1	1	1	2	48
13	2	9	10	13	8	10	6	2	4			1	1	66
14	5	15	11	23	16	8	6	5						89
15	6	16	12	10	6	4	1		1					56
16	9	21	13	3	1	2	1							50
17	6	14	4				1							25
18		1	1											2
19	1													1
Y	33	92	73	58	45	39	21	14	8	2	1	2	3	391

X = midclasses weight in grams.

Y = midclasses sugar percent.

Correlation = -.3044 ± .0395.

Mean weight in grams = 396.9309.

Mean sugar percent = 13.6189.

(4). Relationships (Correlations) Topped Beets.

The purpose of presenting the data for topped beets is to determine the influence the crown may have had on the results of the whole beets. This is important because the high crown was a direct result of leaf spot. Leaf spot, a fungus disease, killed the old leaves and the beet sent out new ones. This resulted in a building up of the crown.

A. Specific Gravity vs. Sugar Content.

(a) Topped healthy beets.

1. Specific Gravity calculated.

Table 16 shows the correlation for 283 beets to be .6561 ± .0228. This is an increase over the corresponding table for whole beets.

-Table 16-

Correlation specific gravity (calculated) to sugar content.

Topped Healthy Beets.

X--	1.025	1.035	1.045	1.055	1.065	1.075	1.085	1.095	Total
10		3	1						4
11	1	7	7	1					16
12		7	17	6		1			31
13		1	13	25	5				44
14			19	31	15	1			66
15		4	3	21	17	3			48
16			5	8	20	10	1		44
17				4	13	7	2		26
18				1			1	1	3
19				1					1
Y	1	22	65	98	70	22	4	1	283

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .6561 ± .0228.

Mean specific gravity = 1.0556.

Mean sugar percent = 14.2155.

2. Specific Gravity by Salt Solution.

Table 17 shows a correlation of .5331 ± .0317. The coefficient is over sixteen times its probable error.

-Table 17-

Correlation between specific gravity by salt solution and sugar content. Topped Healthy Beets.

X--	1.025	1.065	
10	3		3
11	11	3	14
12	8	15	23
13	3	29	32
14	1	48	49
15	1	39	40
16		41	41
17		25	25
18		3	3
19		1	1
			Total
Y	27	204	231

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .5331 ± .0317.

Mean specific gravity = 1.0603.

Mean sugar percent = 14.3549.

(b) Topped Healthy and Diseased Beets (not hollow).

Table 18 shows the correlation for 309 beets to be .7654 ± .0235. The combining of the diseased and healthy beets has increased the relationship.

-Table 18-

Correlation between specific gravity and sugar content.

Topped Healthy and Diseased Beets (not hollow).

X	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	1.095	Total
2		1									1
4				1							1
5		1									1
6	1										1
7		3	2								5
8		1	2								3
10		1	3	4	2						10
11			2	9	6	1					18
12			2	7	19	6		1			35
13			1	2	13	25	5				46
14					19	31	15	1			66
15				4	3	21	17	3			48
16					5	8	20	10	1		44
17						4	13	7	2		26
18						1			1	1	3
19						1					1
Y	1	7	12	27	67	98	70	22	4	1	309

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .7654 ± .0235.

Mean specific gravity = 1.0531.

Mean sugar percent = 13.7702.

2. Specific Gravity by Salt Solution.

Table 19 including 255 beets show a correlation of .6782 ± .0228. This is an increase over the coefficient with healthy beets alone.

-Table 19-

Correlation between specific gravity by salt solution to sugar content. Topped Healthy and Diseased Beets (not hollow).

X	1.025	1.065	
2	1		1
4	1		1
5	1		1
6	1		1
7	4		4
8	3		3
10	8		8
11	12	4	16
12	11	16	27
13	5	29	34
14	1	48	49
15	1	39	40
16		41	41
17		25	25
18		3	3
19		1	1
Y			Total
	49	206	255

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .6782 ± .0228.

Mean specific gravity = 1.0573.

Mean sugar percent = 13.8471.

(c) Topped Healthy, Diseased, and Hollow Beets.

1. Specific Gravity Calculated.

Table 20 shows a correlation of .7553 ± .0152. The addition of the hollow beets has slightly decreased the coefficient of correlation.

-Table 20-

Correlation between specific gravity (calculated) and sugar content. Topped Healthy, Diseased and Hollow beets.

X-	1.005-	1.015-	1.025-	1.035-	1.045-	1.055-	1.065-	1.075-	1.085-	1.095-	
2		1									1
4				1							1
5		1									1
6	1										1
7		3	2								5
8		1	2								3
9			1								1
10		1	3	5	2						11
11			2	11	9	1					23
12			2	9	23	11		1			46
13			1	3	14	28	8				54
14				1	25	39	17	1			83
15				4	4	24	17	4			53
16					5	8	23	11	1		48
17						4	13	7	2		26
18						1			1	1	3
19						1					1
Y											Total
	1	7	13	34	82	117	78	24	4	1	361

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .7553 ± .0152.

Mean specific gravity = 1.0527.

Mean sugar percent = 13.6897.

2. Specific Gravity by Salt Solution.

Table 21 shows the coefficient of correlation has decreased when compared with the correlation of Table 19. The correlation is .6663 ± .0225.

-Table 21-

Correlation between specific gravity by salt solution and sugar content. Topped Healthy, Diseased and Hollow beets.

X--	1.025	1.065	
2	1		1
4	1		1
5	1		1
6	1		1
7	4		4
8	3		3
9	1		1
10	9		9
11	14	4	18
12	13	18	31
13	7	29	36
14	2	54	56
15	2	42	44
16		44	44
17		25	25
18		3	3
19		1	1
			Total
Y	59	220	279

X = midclasses specific gravity.

Y = midclasses sugar percent.

Correlation = .6663 ± .0224.

Mean specific gravity = 1.0565.

Mean sugar percent = 13.8064.

B. Specific Gravity vs. Weight.

(a) Topped Healthy Beets.

1. Specific Gravity Calculated.

Table 22 shows the results with 283 topped beets when the specific gravity is compared with weight. The coefficient of correlation is -.2007 ± .0385.

-Table 22-

Correlation between specific gravity (calculated) and weight.

Topped Healthy Beets.

X--1.025--1.035--1.045--1.055--1.065--1.075--1.085--1.095-

100		6	12	17	22	9	1		67
200		4	15	31	11	7	3		71
300		3	9	17	14	3		1	47
400	1	3	10	15	14	2			45
500		3	6	9	5				23
600		1	7	6	3				17
700		1	4	3	1	1			10
800		1	1						2
1100			1						1
Y									Total
	1	22	65	98	70	22	4	1	283

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.2007 ± .0384.

Mean specific gravity = 1.0563.

Mean weight in grams = 297.8798.

2. Specific Gravity by Salt Solution.

Table 23 gives the results of 231 beets tested by salt water solution. The correlation is -.2251 ± .0421.

-Table 23-

Correlation between specific gravity (salt solution) and weight. Topped Healthy Beets.

X--	1.025	1.065	
100	3	63	66
200	4	55	59
300	4	32	36
400	6	22	28
500	4	14	18
600	3	12	15
700	2	3	5
800	1	1	2
900		1	1
1000		1	1
Y			Total
	27	204	231

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.2251 ± .0421.

Mean specific gravity = 1.0603.

Mean weight in grams = 283.1169.

(b) Topped Healthy and Diseased Beets (not hollow).

Table 24 shows that the addition of diseased beets has decreased the relationship to a point where it is not significant. The correlation is -.0748 ± .0355. The coefficient of correlation is a little over twice its probable error.

-Table 24-

Correlation between specific gravity (calculated) and weight. Topped Healthy and Diseased Beets (not hollow).

X---	1.005	1.015	1.025	1.035	1.045	1.055	1.065	1.075	1.085	1.095	Total
100		2	2	9	12	17	22	9	1		74
200	1	4	6	5	15	31	11	7	3		83
300			2	3	9	17	14	3		1	49
400		1	1	4	11	15	14	2			48
500			1	3	6	9	5				24
600				1	7	6	3				17
700				1	4	3	1	1			10
800				1	1						2
900					1						1
1000					1						1
Y Total	1	7	12	27	67	98	70	22	4	1	309

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.0748 ± .0354.

Mean specific gravity = 1.0530.

Mean weight in grams = 293.2039.

2. Specific Gravity by Salt Solution.

Table 25 shows a correlation of -.1454 ± .0413. The coefficient is less than four times its probable error.

-Table 25-

Correlation between specific gravity (salt solution) and weight. Topped Healthy and Diseased Beets (not hollow).

X--	1.025	1.065	
100	8	65	73
200	15	55	70
300	7	32	39
400	7	22	29
500	4	14	18
600	3	12	15
700	2	3	5
800	2	1	3
900	1	1	2
1000		1	1
Y			Total
	49	206	255

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.1454 ± .0413.

Mean specific gravity = 1.0573.

Mean weight in grams = 279.6079.

(c) Topped Healthy, Diseased and Hollow Beets.

1. Specific Gravity Calculated.

Table 26 shows the results with 361 beets. A correlation of -.1021 ± .0351. The coefficient is less than three times the probable error.

-Table 26-

Correlation between specific gravity (calculated) and weight.

Topped Healthy, Diseased and Hollow Beets.

X--	1.005-	1.015-	1.025-	1.035-	1.045-	1.055-	1.065-	1.075-	1.085-	1.095-	Total
100		2	2	9	13	17	22	9	1		75
200	1	4	6	5	16	33	13	8	3		89
300			2	5	12	22	17	4		1	63
400		1	1	6	15	21	15	2			61
500			1	5	9	12	6				33
600			1	1	10	7	4				23
700				1	4	3	1	1			10
800				1	1						2
900					1						1
1000					1	1					2
1100				1							1
1200						1					1
Y	1	7	13	34	82	117	78	24	4	1	361

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.1021 ± .0351.

Mean specific gravity = 1.0527.

Mean weight in grams = 312.1883.

2. Specific Gravity by Salt Solution.

Table 27 gives the results with 279 beets and shows a correlation of -.1769 ± .0391.

-Table 27-

Correlation between specific gravity (salt solution) and weight. Topped Healthy, Diseased and Hollow Beets.

X--	1.025	1.065	
100	9	65	74
200	16	60	76
300	8	37	45
400	9	25	34
500	7	15	22
600	5	12	17
700	2	3	5
800	2	1	3
900	1	1	2
1000		1	1
Y			Total
	59	220	279

X = midclasses specific gravity.

Y = midclasses weight in grams.

Correlation = -.1769 ± .0391.

Mean specific gravity = 1.0565.

Mean weight in grams = 285.3047.

C. Sugar Content vs. Weight.

(a) Topped Healthy Beets.

Table 28 shows a correlation of -.4639 ± .0315. The correlation is significant. The coefficient is practically 15 times its probable error.

-Table 28-

Correlation between weight of beet in grams and sugar content.

Topped Healthy Beets.

X	100	200	300	400	500	600	700	800	900	1000	
10					1	1	2				4
11	2	5	2	4	2	1					16
12	3	5	4	4	6	2	4	1		1	30
13	2	11	8	10	5	6	2				44
14	10	13	15	16	6	5	2				67
15	12	14	10	8	2	1		1			48
16	20	17	4	2		1					44
17	17	4	4		1						26
18		2	1								3
19	1										1
Y											Total
	67	71	48	44	23	17	10	2		1	283

X = midclasses weight in grams.

Y = midclasses sugar percent.

Correlation = -.4639 ± .0314.

Mean weight in grams = 297.5261.

Mean sugar percent = 14.2226.

(b) Topped Healthy and Diseased Beets (not hollow).

Table 29 shows the effect of adding diseased beets. The correlation is decreased to $-.2903 \pm .0351$.

-Table 29-

Correlation between weight in grams and sugar content. Topped Healthy and Diseased beets (not hollow).

X	100	200	300	400	500	600	700	800	900	1000	Total
2	1										1
4								1			1
5				1							1
6		1									1
7		5									5
8		2	1								3
9			1								1
10	1	2		1	1	1	2				8
11	3	6	2	5	2	1			1		20
12	5	6	4	4	6	2	4	1		1	33
13	4	11	8	10	5	6	2				46
14	10	13	15	16	6	5	2				67
15	12	14	10	8	2	1		1			48
16	20	17	4	2		1					44
17	17	4	4		1						26
18		2	1								3
19	1										1
Y	74	83	50	47	23	17	10	3	1	1	309

X = midclasses weight in grams.

Y = midclasses in sugar percent.

Correlation = -.2903 ± .0351.

Mean specific gravity = 293.8512.

Mean sugar percent = 13.7734.

(c) Topped Healthy, Diseased and Hollow Beets.

Table 30 shows that the addition of the hollow beets scarcely changed the correlation. The correlation is -.3007 ± .0321.

-Table 30-

Correlation between weight in grams and sugar content.

Topped Healthy, Diseased and Hollow Beets.

Y \ X	100	200	300	400	500	600	700	800	900	1000	1100	1200	Total
2	1												1
4								1					1
5				1									1
6		1											1
7		5											5
8		2	1										3
9			1			1							2
10	1	2		1	3	1	2						10
11	3	6	3	5	2	2			1				22
12	5	7	5	8	10	3	4	1		3		1	47
13	5	11	13	12	5	6	2			1			55
14	10	16	19	21	6	7	2						81
15	12	16	11	8	4	2		1					54
16	20	18	6	2	1	1							48
17	17	4	4		1								26
18		2	1										3
19	1												1
Total	75	90	64	58	32	23	10	3	1	4		1	361

X = midclasses weight in grams.

Y = midclasses in sugar percent.

Correlation = $-.3007 \pm .0521$.

Mean weight in grams = 313.5734.

Mean sugar percent = 13.6897.

D. Summary of Correlations.

-Table 31-

Correlations collected.

A - Healthy Beets.

B - Healthy and Diseased Beets (not hollow).

C - Healthy, Diseased and Hollow Beets.

Relation of Specific Gravity to Sugar Content.

	-Whole Beets-		-Topped Beets-	
	Calculated	Salt Solution	Calculated	Salt Solution
A =	.54 ± .03	.59 ± .03	.66 ± .02	.53 ± .03
B =	.69 ± .02	.62 ± .03	.76 ± .02	.68 ± .02
C =	.69 ± .02	.62 ± .03	.76 ± .02	.67 ± .02

Relation of Specific Gravity to Weight of Beets.

	-Whole Beets-		-Topped Beets-	
	Calculated	Salt Solution	Calculated	Salt Solution
A =	-.10 ± .04	-.22 ± .04	-.20 ± .04	-.22 ± .04
B =	-.02 ± .03	-.17 ± .04	-.07 ± .03	-.14 ± .04
C =	-.10 ± .03	-.18 ± .04	-.10 ± .03	-.17 ± .04

Relation of Weight to Sugar.

	-Whole Beets-	-Topped Beets-
	Calculated	Calculated
A =	-.46 ± .03	-.46 ± .03
B =	-.28 ± .03	-.29 ± .04
C =	-.30 ± .04	-.30 ± .03

An examination of the correlation coefficients, as shown in Table 31 obtained between the specific gravity and the sugar content of Michigan grown beets, shows that the relationship is sufficient to allow for the separation of beets into groups of high and low average sugar content by means of a 1.045 salt solution. This solution is not dense enough to prevent a number of beets with a medium low sugar content from sinking. Table A shows that 22 of the 154 beets that sank tested less than 13.5 per cent sugar. The number that sink decreases rapidly with an increase in the density of the solution. Data obtained by the writer in this investigation but not reported in this thesis, shows that a 1.050 salt solution eliminated all except one of the beets below 13.5 per cent. This means that a denser solution such as 1.060 would float off all but a few of the exceptionally high average sugar content beets.

IV--FACTORS AFFECTING RELATIONSHIPS.

(1) Disease (Cercospora beticola) Leaf Spot.

Leaf spot is a fungus disease that attacks the leaves of the sugar plant and in case of bad infection spreads rapidly over the entire leaf surface killing the leaves. High humidity increases the rapidity of the

Leaf spot has killed lower leaves.

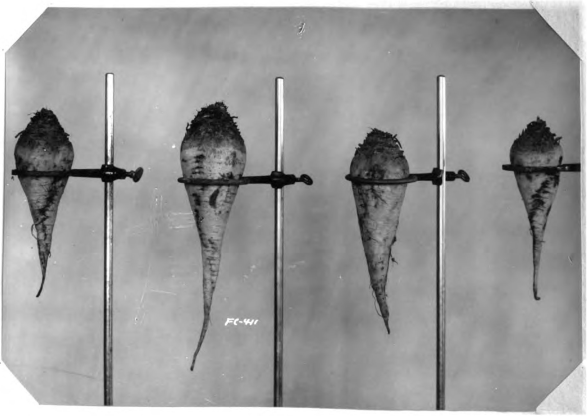
New leaves have replaced the old
that were killed by leaf spot.

A normal beet (left) and diseased beet (right).
Leaf spot has destroyed the normal structure of the beet.

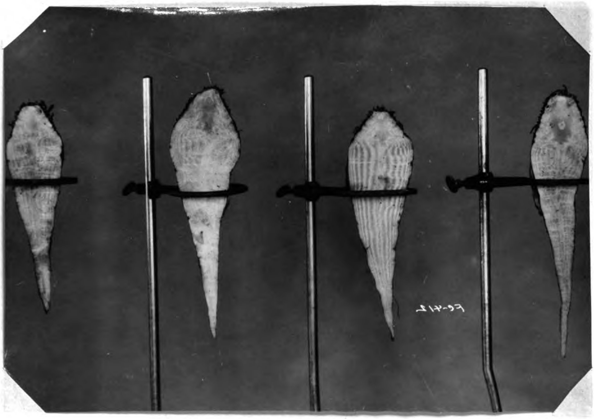
A progeny resisting leaf spot.

attack. Low areas and early fields with dense foliage are attacked before high areas or late field with a small amount of foliage. The lower leaves succumb first because of greater humidity. During 1921, leaf spot destroyed all of the old leaves of many beets in Michigan. In its fight for existence the beet sent up new leaf circles, gradually increasing the height of the crown, in many instances from 2 to 5 inches higher than it would have been. The effect of sending up new leaves on the sugar content of the beet is well explained in Circular No. 121 Bureau of Plant Industry, "Control of Sugar Beet Leaf Spot" by V. W. Pool and M. B. McKay, "If too many leaves are killed the beet plant can only maintain its normal sugar production temporarily reducing the amount in the root. Accordingly the sugar from the root is transferred and used in the development of new leaf tissue. Since this sometimes requires 3 to 5 per cent of the sugar content of the root the final total is correspondingly reduced." The average sugar content of the diseased beets used in this investigation was 9.04 per cent in comparison with 14.14 per cent for healthy beets.

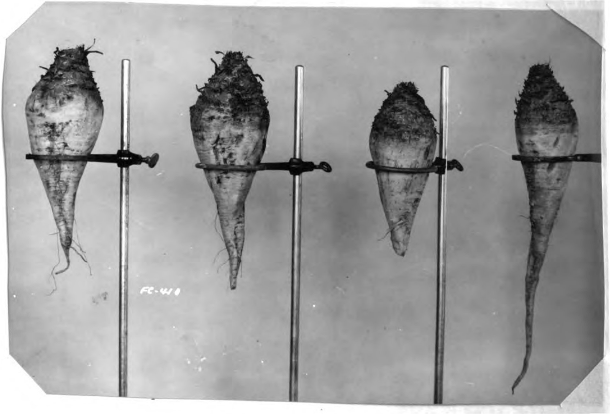
Table 31 shows that the addition of the diseased beets to the healthy beets has increased the correlation between specific gravity and sugar content. This increase



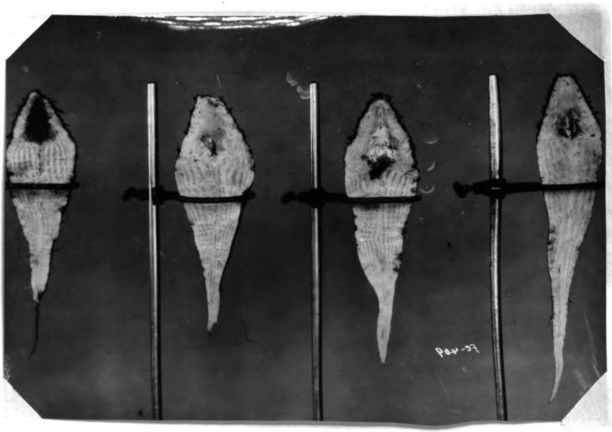
Types of beets that sink on 1.045 solution.



Structure of beets that sink on 1.045 solution.



Types of beets that float on 1.045 solution.



Many beets are hollow that float on 1.045 solution.

seems to indicate that the diseased beets have a higher correlation. This is not true. The correlation is .45 ± .10 in comparison with .54 ± .03 for healthy beets. The combining of these two populations results in a correlation of .59 ± .02. Table 3 shows that the diseased beets are entirely floated off by the (1.045) salt solution, as they have a lower specific gravity and a lower sugar content.

The removal of the crown increased the correlation in all but one case. This was in the case of healthy beets when tested with salt solution. The high crowns on the beets produced abnormal populations and reduced the correlation. The specific gravity of many crowns was unity.

(2). Size.

The correlation, -.30 ± .04, obtained between weight and sugar content for the entire population, is very similar to the correlation reported by Harris in his book "Sugar Beets in America". The healthy beets alone however, gave a much higher relationship. Because of this correlation it might be expected that a salt solution of a different density would be required when separating large or small beets. The correlation between specific gravity and weight does not show this to be true. The correlation is only slightly significant when the

healthy beets are tested by a salt solution. These figures indicate that a salt solution of a given density will separate all beets of medium size and a solution of different density only needs to be used for the separation of beets of extreme sizes.

V--GENETIC METHODS

Mother beets are known genetically by their progeny records. It is not sufficient that the mothers have a high sugar analysis, they must breed true. By breeding true is meant the ability of mother beets to reproduce their kind. The nearer they come to this goal the more valuable they are for breeding stock.

Little is known regarding the exact nature of the inheritance of sugar in the sugar beet. It is probable that several factors are involved. T. G. Palmer states in the introduction to his book "Sugar Beet Seed" "Originally containing but 4 to 5 per cent of sugar of which Achard in 1812 was able to recover 2.27 per cent, beets now contain 16 to 20 per cent of sugar, 85 per cent of which is recoverable". This increase has come through the selection of high testing mother beets. That high testing mother beets do not necessarily breed true is shown by the work of C. D. Smith, Director of the Michigan Station, reported in the station report of 1905.

"At the harvest of 1902 certain mother beets were selected, first by their form and next by the polariscope. Those that tested high in sugar are set out, in 1903, and from them seed was harvested. This seed was sown in 1904 and the resulting beets tested. It was found that the great majority of the mother beets did not produce seed which would in turn grow beets as rich as the mother beets themselves". These facts indicate that the sugar producing factors are of a dominant nature. They are the allogenes of each genoplex (reaction between each epistatic sugar factor). This shows that improvement comes through the selection of the allozygote for at least one genoplex. Allozygous and heterozygous mother beets grown under practically the same conditions and allowed to reach practically the same size can therefore be separated from the protozygous by a salt solution or by chemical analysis. Care must be taken to select beets that are high testing because of their heredity and not because of their envirenment. On the average the dominant types (allozygotes and heterozygotes) would have as good an environment as the recessive (protozygotes) and the selection of a few of the highest testing beets from a large population should give allozygous and heterzygous beets for breeding work. These two

classes can be distinguished only by their progeny records. Methods of doing this will be discussed under the different genetic ways of procedure.

(1) Allogamy (Open Pollination).

A. No Selection.

If one selects seed from open pollinated unanalyzed mother beets and proceeds by such a method, generation after generation, he is practicing no selection in allogamy. This method is discussed in order to attempt an answer to the question: will the sugar content decrease unless rigid selection is practiced?

Any selected population is unstable and will reach a new and stable equilibrium in one generation with no selection.

Suppose a population as left by selection contains equal numbers of allozygotes and heterozygotes with no protozygotes and that this population is allowed to cross pollinate. An equal number of allozygous and heterozygous mother beets will produce male and female gametes in ratio of three allogenes to one protogene. The recombination of these gametes will give nine allozygotes, six heterozygotes and one protozygote. Under no selection, this new population will continue to produce male and female gametes in the ratio of three

allogenes and one protogene, and recombining to maintain the 9 : 6 : 1 ratio until disturbed by selection. The percentage of allozygotes and heterozygotes in the population has decreased from 100 to 93.75 per cent. This decrease means a material reduction in the sugar percentage and would account for high analyzing mother beets not breeding true, which would be the case so long as the population contains heterozygous beets.

B. Mass Selection.

If one harvests seed from allozygous and heterozygous open pollinated mother beets collectively and re-selects the highest analyzing beets produced from this seed, he is practicing mass selection in allogamy. The mothers may be selected by floating off the beets with low sugar content on a salt solution leaving a group with a high average sugar content. An actual chemical analysis of the best group will discover the beets with the highest sugar content. These are either allozygous or heterozygous for high sugar production. The elimination of the protozygous beets gradually reduces the protozygous inheritance in any race and increases the allozygous inheritance. This results in a gradual improvement in the sugar content.

The relative size is an essential point to consider when making selection. If the beets are of equal size, this is an indication that each beet had practically the same chance to develope. If small beets are to be selected they should have a higher sugar content than is necessary for the larger beets to contain. This is because of the correlation between size and sugar content.

The mixture of allozygous and heterozygous beets that are finally selected are planted in an isolated group and allowed to cross pollinate. The protozygous inheritance is continued in the race through the heterozygotes. This makes it necessary to repeat rigid selection generation after generation. This method of improvement is slow at best, and genetic expectations indicate that the hetero-zygotes can never be entirely eliminated.

C. Allozygous X Mass Selection.

If one selects seed from allozygous mother beets that are fertilized by pollen from the mixed allozygous and heterozygous population, he is practicing allozygous x mass selection in allogamy. The high testing mother beets are first selected as outlined under mass selection but it is necessary to distinguish the allozygotes from the heterozygotes. This is done at the Michigan Station by planting the seed from each individual mother beet in a progeny row in comparison with a standard variety. Each progeny is compared directly with the standard growing on each side of it. Since the comparisons are all made with the standard they can be compared directly with each other. It is considered that the progenies having the highest average record when compared with the standard come from allozygous mothers, while those with lower records come from heterozygous mothers. The best progenies are saved and planted in an isolated group for continued breeding. By this method the percentage of protozygous inheritance in a race decreases much faster than with mass selection. In fact genetic expectations show that the ratio of allozygotes to heterozygotes in the fifth generation of allozygous x mass selection is not reached until the 23rd generation of mass selection.[1]

D. Allozygous X Allozygous Selection.

If one selects seed from allozygous mother beets that are only fertilized by allozygous beets, he is practicing allozygous x allozygous selection in allogamy. Before this can be done allozygous mothers must be

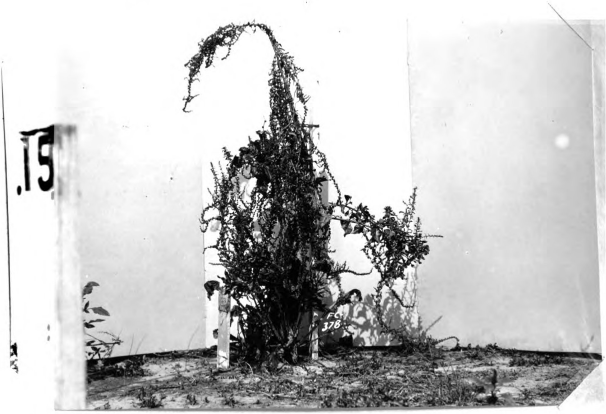
---

[1] Discussed in the thesis: "Methods of Breeding the Sugar Beet" by Hugh B. Smith, pp. 33-35.

Comparing progenies with a standard variety
as outlined under allozygous x mass selection in allogamy.

Harvesting beets from breeding plats.

Taking weights of each individual lot.



Isolated beet. Practicing close fertilization.

determined as outlined under allozygous x mass selection. While this is being done advantage must be taken of the perennial habit of the sugar beet. The original mothers can be saved by siloing and then replanting to produce a second seed crop. After the allozygous mothers have been selected by their progeny records, they are stored while the heterozygous mothers are discarded. The following spring the allozygous mothers are planted in an isolated group or better still in groups of two and allowed to cross pollinate. Such a method brings together the highest possible producers from any population and allows seed to be produced from allozygous mothers in two generations. It offers the greatest chance for improvement of any method under allogamy.

(2) Autogamy (Self Fertilization).

A. No Selection.

No selection in autogamy requires the selection of mother beets at random and without analysis, the isolation of these beets to produce seed, the remixing of this seed to produce a crop of beets and the reselection of mothers at random to be reisolated to insure autogamous mating. Genetic expectations show that the number of heterozygotes is rapidly reduced and in the end the population contains a mixture of 2^t pure lines, where

t is the number of genoplexes involved.[1] For each genoplex the population would contain an equal number of allozygotes and protozygotes. The presence of the protozygotes decrease the sugar content. Allozygous races could be isolated at any time by practicing allozygous x allozygous selection.

B. Mass Selection

Mass selection requires the selection of phenotypically allozygous mothers, the isolation of these to produce seed and the remixing of the seed before growing another crop. According to genetic expectations it would require the same length of time to produce a pure line as under no selection.[1] Only one pure line will be produced for each genoplex involved, i. e. the protozygous beets will be eliminated. Rigid mass selection would rapidly reduce the number of heterozygotes and increase the percent sugar to the limit of the allozygous lines.

C. Allozygous X Allozygous.

If one selects high analyzing mother beets and isolates these by space so they will produce close fertilized seed and eliminates the heterozygotes by progeny records, he is practicing allozygous x allozygous

[1] Thesis: Methods of Breeding the Sugar Beet, by Hugh B. Smith.

Practicing allozygous mating.

Progeny from a high producing mother beet.

selection in autogamy. The seed is harvested from each individual beet and tested in comparison with a standard variety as outlined under allozygous x mass selection in allogamy. The progenies coming from heterozygous mothers are discarded. Each allozygous progeny is planted in an isolated group and allowed to cross pollinate. This allows for the production of high producing lines in one generation. It is the quickest possible way of producing an allozygous race of beets.

One objection to this method is the danger of reducing the vigor of the race through inbreeding. The vigor can be reacquired by crossing several of the highest producing lines.

(3) Comparing Resulting Methods.

Allozygous x allozygous in autogamy is the only method that allows the breeder to test out the ability of the mother beet to transmit high sugar content uninfluenced by the male inheritance. Under allozygous x allozygous in allogamy the breeder must assume that the mixed pollen coming from allozygous and heterozygous beets influences all the mothers equally and any variation in their progenies is due to the inheritance from the mother. This may or may not be true. Then the difficulty of storing the mothers

for two extra seasons makes the method hard to practice. These are the only two genetic methods however, that offer any chance for rapid improvement.

Allozygous x mass in allogamy overcomes the continued storing of the allozygous mother beets but does not allow for as rapid improvement.

VI--CONCLUSIONS (Use of Methods)

(1) By Experiment Stations.

It is evident from the material offered in this thesis that chemical, specific gravity, and genetic methods of testing mother beets for sugar content are all closely interrelated. One is a continuation of the other. The first two are methods of eliminating low analyzing mother beets and leaving a population of high analyzing mothers to be tested for their ability to transmit high sugar content by genetic methods.

The experiment station can make use of all three methods. The low analyzing beets can be eliminated from large populations with very little expense by the specific gravity method, and the selected group further reduced to include a few high analyzing beets by the chemical method. The few high analyzing beets can be tested for ability to transmit sugar by the most promising genetic methods as outlined in this thesis. The method to be used depends on the pedigree of the mother beets.

(2) Commercially.

The chemical and genetic methods of determining the sugar content of mother beets are of little value on a large commercial scale. The expense and labor involved makes these methods impractical, except in the case of the small breeding plats used by the commercial grower. The specific gravity method allows the grower cheaply and rapidly to float off the beets with low sugar content, leaving a group with a high average sugar content to be planted for commercial seed. Care must be taken to maintain the density of the salt solution used for floating off the beets. This can be done by finding a beet that floats in the salt solution in an upright position. Any material change in the density of the solution will alter the position of the beet.

(3) Advantages.

The advantages to be derived from the chemical, specific gravity, and genetic methods are classified as follows:

-Chemical Method-

(1) Gives the sugar content of individual beets.
(2) Allows for the selection of high testing mother beets.

-Specific Gravity-

(1) Separates the beets into two groups, one with a high and the other with a low average sugar content.

(2) Reduces the expense of eliminating low testing mother beets.

(3) Eliminates the diseased and hollow beets.

-Genetic Method-

(1) Distinguishes mother beets by their ability to transmit high or low sugar content to their progenies.

(2) On this basis it is possible to distinguish allozygous from heterozygous mother beets and to eliminate the heterzygote.

(3) Makes it possible to recombine the allozygous mothers.

(4) Allows for the isolation of progenies from allozygous mothers.

(4) Disadvantages.

-Chemical and Specific Gravity Methods-

(1) Danger of being deceived by the environment and obtaining high testing mother beets that have little or no ability to transmit high sugar content to their progeny.

(2) Does not distinguish heterozygous from allo-
zygous mothers.

(3) Methods not accurate enough to prevent a few protozygous mother beets entering the selected class.

-Genetic Method-

(1) More expensive.

(2) Requires more time.

These two objections are offset by better end results.

-ACKNOWLEDGMENT-

The writer wishes to acknowledge his indebtedness to F. A. Spragg for his many helpful suggestions in handling this investigation and for his thorough criticism of the work. He is indebted to Hubert Brown for valuable suggestions. He is also indebted to J. F. Cox and F. A. Spragg for the final review of this thesis.

-CITED LITERATURE-

Früwirth, C. 1910. Die Züchtung Der Landwirtschaftlichen Kulturpflanzen.

Harris, F. S. 1919. The Sugar Beet in America.

Palmer, T. G. 1918. Sugar Beet Seed.

Pool, V. W. and McKay, M. B. 1912. Control of Sugar Beet Leaf Spot. Cir. 121 Bureau of Plant Industry.

Smith, C. D. 1905. Michigan Station Report.

Smith, Hugh B. 1921. Methods of Breeding the Sugar Beet. Thesis for M. S. at Michigan Agricultural College.

Ware, L. S. 1898. Sugar Beet Seed.