5-1966

Estimation of Irregular Spacing on Sugar Beets and its Effect on their Chemical Measurements and Weight

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ESTIMATION OF IRREGULAR SPACING ON SUGAR BEETS AND ITS EFFECT ON THEIR CHEMICAL MEASUREMENTS AND WEIGHT

by

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A report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Applied Statistics

Plan B

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1966

ACKNOWLEDGMENT

I wish to express my gratitude to Dr. Rex L. Hurst, and Dr. Donald V. Sisson, who have not only guided me in setting up this project, but also encouraged me throughout my academic program. I would like to thank Dr. Dave White for his encouragement during my academic program. I also extend sincere thanks to Professor W. Pope for his valuable help, to Mr. George K. Ryser for his assistance in obtaining and interpreting the original data which were used in this project.

Ahmad A. Aghabeigi

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INTRODUCTION

In an attempt to improve the yield and quality of the sugar beet, many problems arise as to the effect of "growing space" on the individual beets. Large quantities of chemical data can be collected on individual beets and the problem of reducing this data to a suitable and understandable effect of space on the chemical data needs investigating. In the past this reduction process has been accomplished by slow hand calculation methods, thus making it virtually impossible for the scientist to analyze and propose corrective measures at the time they are needed. With the use of high speed computing equipment this need no longer be a major factor of concern to the research worker today, and it is felt that the mathematical models involved can be solved. It is the purpose of this study to develop a program utilizing computers to solve a typical problem of the effect of space on individual beets.

So our objectives are:

1. Development of reduction techniques to obtain the useful statistics in the solution of a beet space problem.

2. A written generalized program to summarize the data collected and obtain a measure of the "growing space" between plotted individual beets with irregular spacing.

3. Solution of the regression model obtained using a high speed computer.

REVIEW OF LITERATURE

In recent years there has been a growing tendency among sugar beet growers both to widen row widths and to increase the spacing between beets within the row. The tendency to widen the spacing of beets within the row has no doubt resulted from the fact that increased spacing speeds both the hand-thinning and hand-topping operation. Increased row width spacing has largely developed along with the development and use of mechanical harvesting equipment. There is also a general feeling that rows should be wider than 20 inches for machines and power equipment to operate most efficiently.

B. Toleman, R. Johnson and A.J. Bigler (4) conducted the row width and spacing studies during three years, 1945 to 1947, in the mountain states area. The main purpose of these studies has been to investigate the effect of increased row widths on production and to find out whether the spacing between beets within the row should be decreased as spacing between the rows is increased.

All the row width and spacing tests utilized a split-plot design. Each row width plot was 8 rows wide and 400 to 800 feet long. These strips were then divided into three or four sub-plots to accommodate the within-the-row spacing treatments. The row width and spacing tests conducted at Granger, Utah, in 1945 included a comparison of 20, 26, 32 and 38-inch row widths and on each row width 8, 12 and 15-inch spacings of beets within the row were compared. It was evident from the data that miximum yield of beets per acre and maximum yield of sugar per acre were produced on 20-inch rows with 12-inch spacing of beets within the row. Increasing spacing within the row and increasing the spacing between rows decreased both tonage and the sucrose content of the beets produced. There was a decrease of from 600 to 800 pounds of sugar per acre as row width was widened from 20 to 26 inches, and the loss of sugar per acre approached 2,000 pounds, or 20 to 25 percent of the yield on 20-inch rows as the row width was widened to 38 inches. It was also very evident from the data that optimum spacing within the row remained more or less constant regardless of row width. This fact indicates that distribution of beets per acre is more important than number of beets per acre. A distribution approaching a square, such as 12-inch spacing on 20-inch rows, was much more efficient than where the space allotment per beet was extremely rectangular in shape as was obtained with 8-inch spacing on 38-inch rows. Under the conditions of this test, 12-inch spacing of beets within the row gave maximum yields.

The decrease in yield in the 1945 test was so rapid as row width was increased that further tests were conducted in 1946 (4) to investigate a much smaller variation in row widths and to determine whether yields could be increased by increasing the number of rows per acre through the use of wide and narrow row width combinations. Row widths studied included a 12-20 inch wide and narrow combination, 20-inch rows, and 24-inch rows. Three variations on spacing within each row width were compared. These within-the-row spacing comparisons were 9.5 inches, 12 inches, and 16 inches. Maximum yields were again obtained with 12-inch spacing within the row, and there was no indication that as row width was increased that there was any advantage in spacing the beets closer than 12 inches in the row. Row width, however, did have a significant effect on the yield of both beets and gross sugar per acre. Yields decreased when row widths varied either way from 20 inches. Increasing row widths from 20 inches to 34 inches resulted in a decrease of sugar per acre as follows: Washington 790 pounds; Idaho 1,332 pounds; South Dakota 250 pounds; and Utah 676 pounds.

As a result of the 1946 tests, interest in the 1947 tests was centered around various wide and narrow row width combinations, which would average the equivalent of 20 to 22-inch rows. The data from the two 1947 tests indicate that uniform width rows 20 inches apart produced higher yields than did any of the wide and narrow combinations averaging 20 inches. The data also support all previous data which indicated a loss in production on all row widths wider than 20 inches. The 20-inch rows produced an average of 504 pounds more gross sugar per acre than the next closest row width treatment. These tests indicated that wherever possible 20-inch rows should continue to be the standard row width, and that where a change is necessary to adjust to machines and power equipment, the next best row width from the standpoint of maintaining production would be one of the following: 18-24-inch or 20-22-inch wide and narrow combinations, or straight 22-inch. The results reported indicated that distribution pattern affected yields to a greater extent than did the range of population per acre which was included in the tests. This is in accord with the findings of Brewbaker and Deming (1) who state that uniformity of stand is relatively more important than the particular spacing used. The decrease in yield from 20 to 26-inch rows also follows the pattern indicated by the work of Brewbaker and Deming. They report a decrease of over 2 tons per acre when row widths were increased from 20 to 24 inches even though populations were greatly increased in the row to compensate for the wider row. In all tests, increasing the space allotment per beet whether within the row or between the rows resulted in decreased sucrose percentage.

Gaskill and Deming (2) in 1938 reported results obtained from a replicated experiment in which 32 strains or varieties of sugar beets were compared under 40 x 40-inch and 10 x 20-inch spacings. The correlation coefficients for varietal performance under the two spacings were found to be 0.62 for weight of root and 0.78 for sucrose percentage, both values being highly significant, in other words there was a fair correlation between the spacings and weight, and also between spacings and sucrose percentage. Individual weights and analyses for 960 roots, representing 6 varities, indicated that variability in weight of root was much less under wide spacing than under normal spacing, the difference being highly significant. Variability in sucrose percentage under the two respective spacings did not differ greatly. These data showed further that, in weight of root, a sample of 10 beets taken at random from 40 x 40-inch spacing was equivalent, in statistical accuracy, to a sample of 24 competitive beets taken at random from 10 x 20-inch spacing.

Deming in 1940, stated that 3 year's results, involving a total of II varieties, showed the same relative trend in yield and sucrose percentage for both 10 x 20-inch and 40 x 40-inch spacings.

EXPERIMENTAL PROCEDURE

The individual beet test for 1965 was planted on the "s" field, North Logan Farm, Cache County, Utah. The test included three self-fertile breeding stock varieties, secregating for mendelian male sterlity, which are called three parents: varieties 0461, 030, and 712. Within each variety a selection was made on the bases of (1) high sucrose, (2) high impurity index, (3) low impurity index. So there were twelve treatments as following:

Variety 0461	Variety 030	Variety 712
1. parent	1. parent	1. parent
2. sugar selection	2. sugar selection	2. sugar selection
3. high impurity index	3. high impurity index	3. high impurity index
4. low impurity index	4. low impurity index	4. low impurity index

The test was planted in a randomized block design with four replications. All beets in each plot were plotted as to location. Each plot contains two rows with unequal number of beets which have unequal spacing within the row There were twelve plots in each replication. The length of the rows were 32 feets, with 1.833 width. The distance of each beet was measured with respect to the zero line.

A study of space occupied by each beet could be obtained in relation to individual beet weight, sucrose percentage, amino N, Na, K, and impurity index value.

The information for each observation is laid out on a card as following:

Column	Identification
1 - 5	Card number
6 - 7	Beet number (for each plot)
8	Punch 1
9 -11	Plot number
12 -14	Distance from the zero line (in feet)
15 -16	Treatment number or variety numbers: 01, 02, ... , 12
17	Replication number
18 -19	Row number
20 -21	Beet number (for each row): 01, 02, 03. . . . the last beet on the row.
22 -23	Project
24 -27	Sugar content xxxx. (grams)
28 -31	Weight xxxx. (grams)
32 -34	Sucrose xx.x (percentage)
35 -39	Impurity index xxxxx. (ratio)
40 -43	Amino N xxxx. P.P.M.
44 -47	NA xxxx. P.P.M.
48 -51	K xxxx. P.P.M.

The following is part of the data obtained from replication one.

Part of the data collected from replication (1) including the seven measurements.

Col. (1) ↑ … Col. (51) ↑

27491011301005021010180011206801650072604600782185 9	9
27492021301012021010280007005001400102405890929207 8	9
27493031301017021010380007704401750046803740320133 1	9
27494041301029021010480015309701580061904650857085 3	9
27495051301036021010580004102601570059405080354120 0	9
27496061301043021010680012207101720062505650431143 9	9
27497071301058021010780007904601720043403740297107 5	9
27498081301066021010880008805801510073405080537165 0	9
22893091301078021010980009305701640056403110537170 1	9
22894101301086021011080008505201640042901670340166 7	9
2289511130'0920210111800010008012500843042205911701	9
22896121301098021011280005403601500077104170684200 3	9
22897131301102021011380004202601610032501510307106 2	9
22898141301113021011480008304901690057504170591139 2	9

Considering the individual beet weight as a dependent variable and sucrose percentage, amino N, Na, K, high impurity index and low impurity index value as independent variables, the correlation elements and regression analysis are obtained by a general multiple regression program.

The simple regression coefficients and the miltiple correlation coefficients of the twelve treatments for the model:

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$ are shown in Tables 1 and 2.

The regression analysis of the above mentioned model for treatment 3 (variety 0461 with high impurity index) which has the minimum R^2 and for treatment 12 (variety 712 with low impurity index) which has the maximum R^2 are shown in Table 3, and labeled as 1 and 2.

The correlation index R^2 as shown in Table 2 are very high for these seven variables, in other words, the degree of association among these variables is very high. By looking at the F values, we see that the effect of all variables is highly significant.

Table 1. The correlation elements for seven variables

Code	Characteristic	Sugar Content	Weight	Sucrose	Impurity Index	Amino N.	Na	K
1.	Sugar Content	+1.000	+.973	+.306	-.071	-.112	-.169	+.382
2.	Weight		+1.000	+.111	+.095	-.025	-.024	+.498
3.	Sucrose			+1.000	-.826	-.404	-.738	-.415
4.	Impurity Index				+1.000	+.672	+.803	+.706
5.	Amino N.					+1.000	+.368	+.344
6.	Na.						+1.000	+.396
7.	K.							+1.000

Table 2. Simple regression coefficients and multiple correlation coefficients

Treatment code	Characteristic	b_o	b_1	b_2	b_3	b_4	b_5	b_6	R^2
1	Var. 046 (parent)	-4310.0	-14.072	+2.514	+286.6	+4.075	-2.224	- .939	.871
2	Var. 046 (sugar selection)	-2528.3	+ .361	+0.083	+165.0	+5.390	-3.445	-1.157	.934
3	Var. 046 (high imp. index)	-2703.0	+12.191	-1.635	+197.4	+4.363	-2.526	-1.119	.848
4	Var. 046 (low imp. index)	-2473.3	+14.211	-2.166	+154.0	+5.326	-3.127	-1.154	.929
5	Var. 030 (parent)	-2084.4	+ 2.591	-0.391	+124.0	+6.083	-3.476	-1.211	.969
6	Var. 030 (sugar selection)	-2081.4	+ 5.870	-0.850	+127.7	+5.793	-3.454	-1.217	.967
7	Var. 030 (high imp. index)	-3375.0	- 2.705	+0.662	+223.1	+4.475	-2.734	-0.980	.925
8	Var. 030 (low imp. index)	-1775.0	+ 7.493	-1.231	+107.8	+6.166	-3.651	-1.390	.916
9	Var. 712 (parent	-2042.1	- 6.235	+1.341	+139.5	+3.880	-2.227	-0.782	.895
10	Var. 712 (sugar selection)	-2749.8	-19.510	+3.567	+182.8	+3.250	-1.846	-0.326	.877
11	Var. 712 (high imp. index)	-2567.8	- 1.977	+0.475	+177.0	+4.862	-3.151	-1.142	.868
12	Var. 712 (low imp. index)	-1661.0	+ 7.960	-1.231	+107.4	+5.630	-3.467	-1.172	.970

Table 3. Regression analysis for model 1

Code	Source	$Df_{(1)}$	$Df_{(2)}$	$M.S._{(1)}$	$M.S._{(2)}$	$F_{(1)}$	$F_{(2)}$
1	Sugar content	1	1	1563709.9	250933.5	24.6**	33.0**
2	Sucrose %	1	1	1250130.3	228893.6	19.6**	30.0**
3	Impurity index	1	1	2908322.0	622612.7	45.7**	82.1**
4	Amino N	1	1	31226748.0	21678915.0	491.4**	2851.7**
5	Na	1	1	11193485.0	6260456.8	176.1**	822.0**
6	K	1	1	11905144.0	6500636.8	187.0**	855.1**
	Model	6	6	11377461.0	8221586.3	179.0**	1081.5**
	Error	192		63536.1	7602.7		
	Total	198		406382.3	248012.0		

$F(192, 1; .05) = 3.90$
$F(192, 1; .01) = 6.78$
$F(192, 6; .05) = 2.15$
$F(192, 6; .01) = 2.88$

DISCUSSION OF THE PROGRAM

To find the effect of irregular spacing on the weight and chemical measurements of sugar beets we need to compute the minimum distances of four nearest beets to each individual beet in four directions, that is, to obtain the distances of the nearest beets to the north, south, east and west.

A computer program was written to calculate these distances after the data cards were sorted by beet numbers and rows and replications. When the source program was processed on Fortran II, the sorted data cards were used directly behind the object deck and the minimum distances were obtained.

Procedure

Considering three rows, we can explain how to find the minima distances of the nearest beets to each individual beet in four directions. We call these distances as D_s, D_n, D_e, D_w where

$D_s \doteq$ Distance to the south

D_n = Distance to the north

D_e = Distance to the east

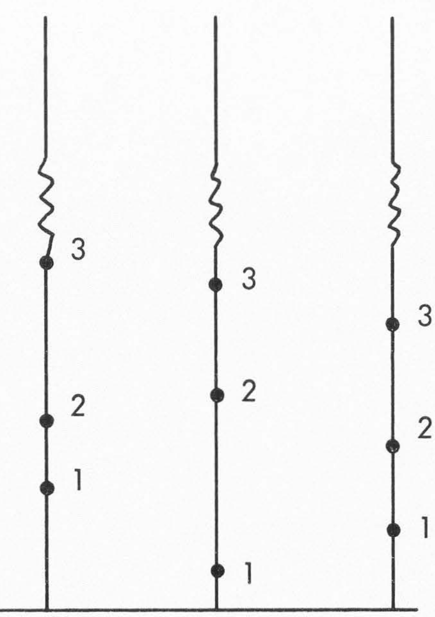
D_w = Distance to the west

Let ;

Row = i

Beet number = j

The jth beet on the ith row = (i, j)



For example, with selecting beet number 2 on the second row, we show the different situations to find these four distances by writing a program. First of all we need several tests for this particular beet.

1. Check whether it is the first beet on the row or not. If it is, there is no need to compute D_s, since D_s for the first beet is given in the data. If it is not, D_s is computed by: $Y_{i,j} - Y_{i,j-1}$

2. Check whether it is the last beet on the row or not. If it is, there is no need to compute D_n, since there are not anymore beets. If it is not, D_n is computed by $Y_{i,j} - Y_{i,j+1}$

3. Check whether if is the first row or not. If it is there is no need to compute D_e, since there are no beets on the east side of the first row. Here, we only compute D_W and skip from all instructions for computing D_e. To compute D_w, some more tests are necessary:

a. Check whether it is the first beet or not. If it is we let the first beet on the next row (i + 1) as L = 1 and

b. Check: is $Y_{i,j} < Y_{i+1,L}$

If $Y_{i,j}$ is less that $Y_{i+1,L}$ (Figure 1) we take the min $\left(\left|Y(i+1,L+1) - Y_{(i,j)}\right|, \left|Y_{(i,j)} - Y_{(i+1,L)}\right|\right)$ which is the minimum of (a) and (b) and call it DB and finding D_W by $\sqrt{DB^2 + (1.833)^2}$. If $Y_{i,j}$ is greater than $Y_{(i+1,L)}$ (Figure 2), we let $L \doteq L + 1$ and

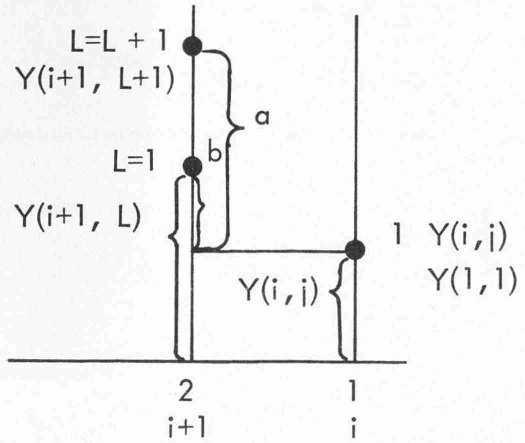


Figure 1. $Y_{(i,j)} < Y_{(i+1,L)}$

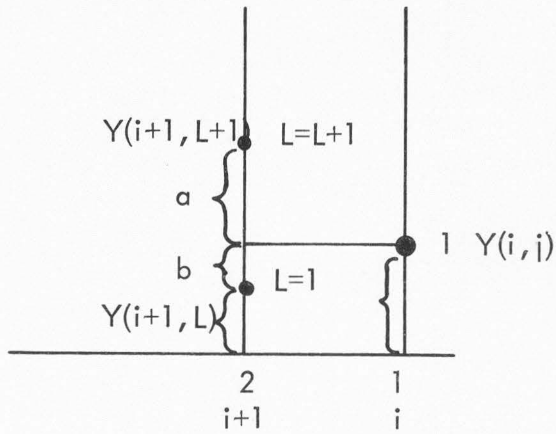


Figure 2. $Y_{(i,j)} > Y_{(i+1,L)}$

c. Check whether L is the last beet on the (i + 1) row or not. If it is the last beet we take the minimum of (a) and (b) and computing D_w. If it is not the last beet we do the same test: $Y_{(i,j)} < Y_{(i+1,L)}$ and continuing the same procedure. In test (a) if it is not the first beet we do the same test: $Y_{(i,j)} < Y_{(i+1,L)}$ and following the same routine. In test (3) if it was not the first row we need to compute D_e and the procedure is exactly the same as D_w except we put i − 1 instead of i + 1 and using K instead of L.

4. Check whether it is the last row or not. If it is the last row, there is no need to compute D_w. If it is not the last row, we compute D_e and D_w.

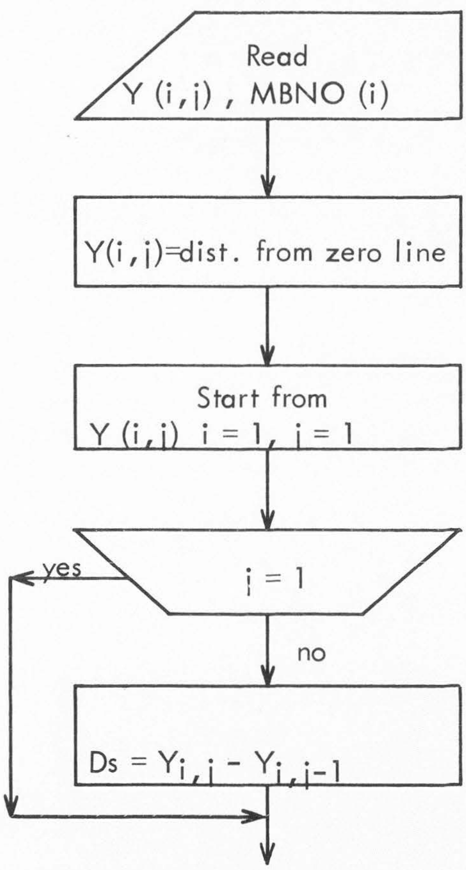
This program can be used for the similar experiments with the following modifications:

a. The ranges of (i) and (j) will change in different experiments.

b. The constant number (1.833) which is the distance between two rows may be changed.

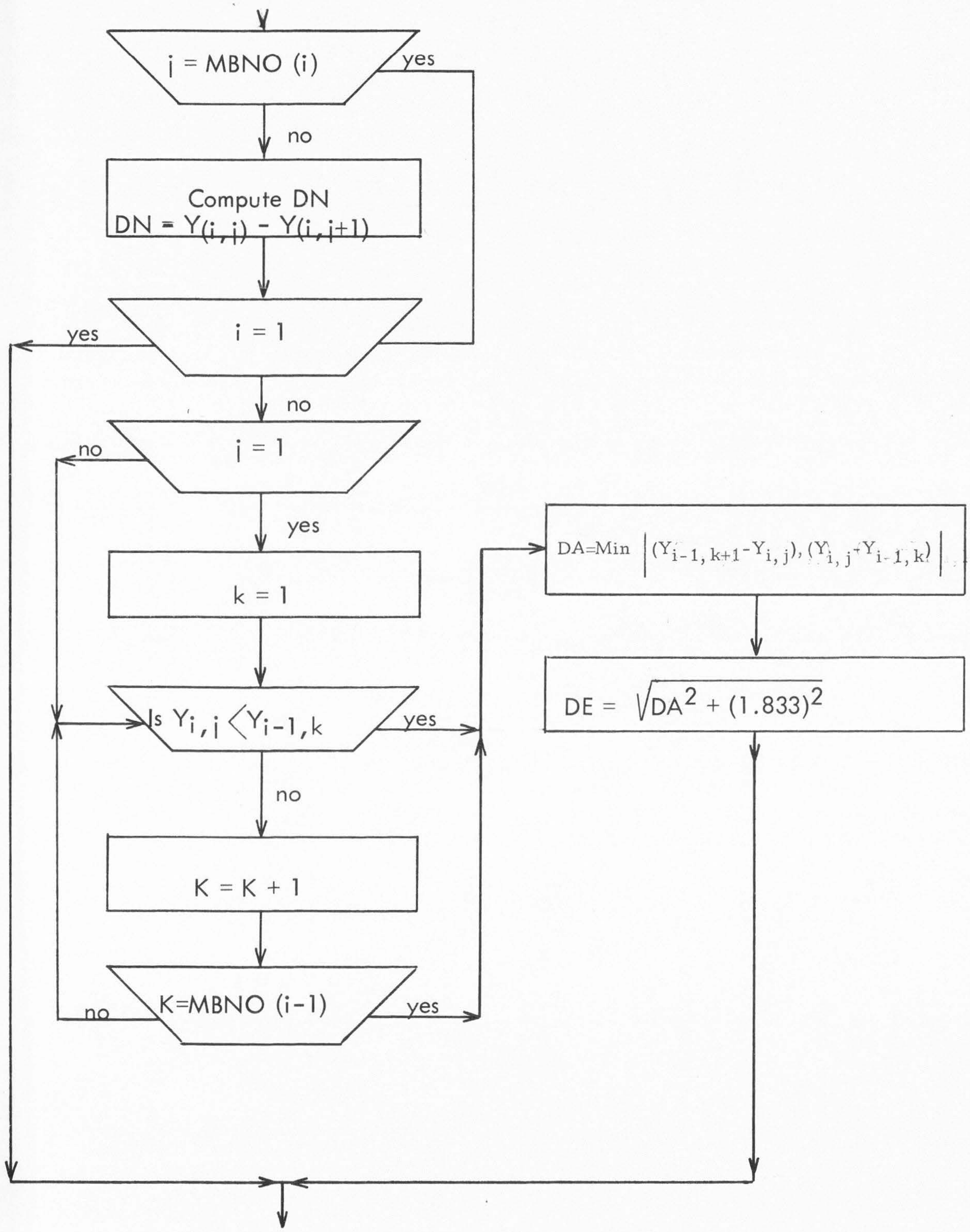
The flow chart and the source program which is written for this problem is shown in next pages. Also to show the result of this program the four minimum distances of a few individual beets are listed next.

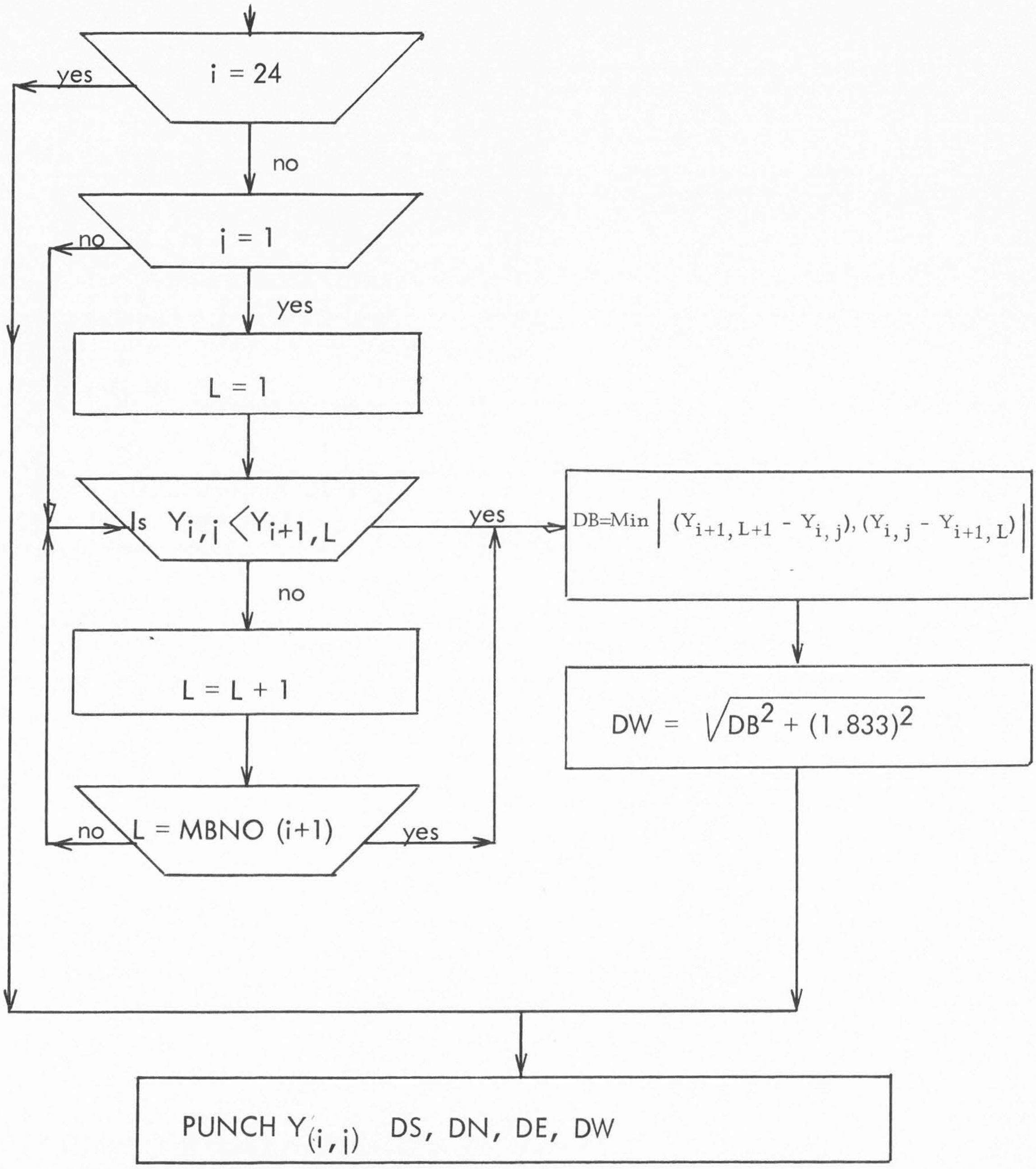
Flow Chart



$1 \leq i \leq 24 \qquad 1 \leq j \leq 47$

MBNO (i) = Maximum Beet Number of ith row.


j = MBNO (i)
yes
no
Compute DN
DN = Y(i, j) - Y(i, j+1)
i = 1
yes
no
j = 1
no
yes
k = 1
Is Yi, j < Yi-1, k
yes
no
K = K + 1
K=MBNO (i-1)
no
yes
DA=Min |(Yi-1, k+1 - Yi, j), (Yi, j - Yi-1, k)|
DE = √(DA² + (1.833)²)



i = 24
yes
no
j = 1
no
yes
L = 1
Is $Y_{i,j} < Y_{i+1,L}$
yes
no
DB=Min $|(Y_{i+1,L+1} - Y_{i,j}), (Y_{i,j} - Y_{i+1,L})|$
L = L + 1
DW = $\sqrt{DB^2 + (1.833)^2}$
L = MBNO (i+1)
no
yes
PUNCH $Y_{(i,j)}$ DS, DN, DE, DW

Source Program

The program to find the minima distances of nearest beets to an individual beet in four directions.

```
      DIMENSION Y (24,47) , MBNO (24)
      DO  10 M=1,24
      IF (M-1) 1,1,5
    1 MBNO (M) =-1
      GO  TO  6
    5 MBNO (M) =0
    6 READ 7,Z,I,J
      Y (I,J) = Z
    7 FORMAT (11X,F3.1,3X,2I2)
      MBNO (M) = MBNO (M) + 1
      IF (I-M) 10,6,10
   10 CONTINUE
      PUNCH  11
   11 FORMAT (21X,2HDS,13X2HDN,13X2HDE,13X2HDW)
      DO  200  I=1,24
      N = MBNO (I)
      DO  200  J=1,N
      DS = O
      DN = O
      DE = O
      DW = O
      IF (J-1)  12,14,12
   12 DS = Y (I,J) - Y (I,J-1)
   14 IF (J-MBNO (I) )  16,18,16
   16 DN = Y (I,J+1) - Y (I,J)
   18 IF (I-1)  20,100,20
   20 IF (J-1)  24,22,24
   22 K = 1
   24 IF (Y (I,J) = Y (I-1,K) )  30,34,226
  226 IF (K-MBNO (I-1) )  26,30,30
   26 K=K + 1
      IF (K-MBNO (I-1) )  24,30,24
   30 IF (K-1)  26,31,32
   31 DA = Y (I-1,1) = Y (I,J)
      GO  TO  35
   32 DA = Y (I,J) - Y (I-1,K-1)
      DAAA=ABSF (Y (I-1),K) - Y (I,J) )
      IF (DA-DAAA)  35,35,33
   33 DA=DAAA
      GO  TO  35
   34 DE=1.833
```

```
     GO  TO  100
 35  DE=SQRF (DA* DA + 1.833* 1.833)
100  IF (I-24)  120,190,120
120  IF (J-1)  124,122,124
122  L = 1
124  IF (Y (I,J) - Y (I + 1,L) )  130,134,326
326  IF (L-MBNO (I + 1) )  126,130,130
126  L = L + 1
     IF (L-MBNO (I +1) )  124,130,124
130  IF (L-1)  126,131,132
131  DB=Y (I + 1m1) - Y (I,J)
     GO  TO  135
132  DB=Y (I,J) - Y (I + 1, L-1)
     DBBB=ABSF (Y (I + 1,L) - Y (I,J)
     IF (DB-DBBB)  135,135,133
133  DB=DBBB
     GO  TO  135
134  DW= 1.833
     GO  TO  190
135  DW=SQRF (DB * DB + 1.833 * 1.833)
190  PUNCH  192,I,J,DS,DN,DE,DW
192  FORMAT (2HY (,13,2H , 13,3H)  ,4F15.5)
200  CONTINUE
     END
```

Sample Output

The minima distances of nearest beets to an individual beet in four directions

Y(1 , 1)	.00000	4.30000	.00000	1.89997
Y(1 , 2)	4.30000	1.00000	.00000	1.92870
Y(1 , 3)	1.00000	1.50000	.00000	1.84387
Y(1 , 4)	1.50000	.50000	.00000	1.89997
Y(1 , 5)	.50000	.60000	.00000	2.08803
Y(1 , 6)	.60000	.70000	.00000	1.87613
Y(1 , 7)	.70000	.60000	.00000	1.85738
Y(1 , 8)	.60000	.80000	.00000	1.92870
Y(1 , 9)	.80000	1.00000	.00000	1.84387
Y(1 ,10)	1.00000	.60000	.00000	1.85738
Y(1 ,11)	.60000	2.00000	.00000	1.85738
Y(1 ,12)	2.00000	3.50000	.00000	1.84387
Y(1 ,13)	3.50000	.60000	.00000	1.99997
Y(1 ,14)	.60000	1.10000	.00000	2.13772
Y(1 ,15)	1.10000	.80000	.00000	1.83300
Y(1 ,16)	.80000	.70000	.00000	1.99997
Y(1 ,17)	.70000	1.50000	.00000	1.87613
Y(1 ,18)	1.50000	.50000	.00000	1.83572
Y(1 ,19)	.50000	.40000	.00000	1.92870
Y(1 ,20)	.40000	1.90000	.00000	1.87613
Y(1 ,21)	1.90000	.70000	.00000	2.36852
Y(1 ,22)	.70000	1.30000	.00000	2.08803
Y(1 ,23)	1.30000	1.50000	.00000	1.85738
Y(1 ,24)	1.50000	.00000	.00000	1.85738

To simplify and save time, we consider the observations of only one variety in different replications. The information of each observation on two cards is laid out as follows:

First card

The information on this card is exactly the same that mentioned before plus the following.

Besides the four minimum distances which are the independent variables, we consider three more independent variables for replications to remove the effect of replications from the regression analysis.

	X_1	X_2	X_3
r_1	1	0	0
r_2	0	1	0
r_3	0	0	1
r_4	-1	-1	-1

Rep. 1

Column	Code
58 - 59	01
61 - 62	00
64 - 65	00

Rep. 2

Column	Code
58 - 59	00
61 - 62	01
64 - 65	00

Rep. 3

Column	Code
58 - 59	00
61 - 62	00
64 - 65	01

Rep. 4

Column	Code
58 - 59	-1
61 - 62	-1
64 - 65	-1

Second card

Column	Identification
1 - 6	$\frac{Ds + Dn}{2}$
8 -13	$\frac{De + Dw}{2}$
18 -19	Row number
20 -21	Beet number
23 -28	Ds (distance to the south)
38 -43	Dn (distance to the north)
53 -58	De (distance to the east)
68 -73	Dw (distance to the west)
79	Replication number

The form of the data for only one variety after collating is shown here. The correlation elements for seven X's in which four X's are the minimum distances and three X's are for replications and six Y's are shown in Table (4).

The simple regression coefficients and the multiple correlation coefficients of treatment (1) (variety 046-parent) for the variables are shown in Table (5). The model is:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7$$

The regression analysis of variable 8 (beet weight) and variable 10 (impurity index) are shown in Table (6). They are labeled as (1) and (2).

$$\text{impurity index} = \frac{10N + 3.5\ Na + 2.5\ K}{\text{Sucrose}}$$

Part of the data of treatment (1) (variety 046 - parent) in four replications

251440113040000110701800186118015800894058206842364						01 00 00		9
140000	222257	0701	150000	130000	256902		187613	11
251450213040130110702800174100017400469033503261470						01 00 00		029
150000	187192	0702	130000	170000	189997		184387	11
251460313040300110703800112076014800684029706781912						01 00 00		9
120000	186784	0703	170000	70000	183572		189997	11
251470413040370110704800116064018100354031601501089						01 00 00		9
065000	186000	0704	70000	60000	187613		184387	11
251480513040430110705800153084018200365018203171486						01 00 00		029
080000	202100	0705	60000	100000	204203		199997	11
251490613040530110706800071043016600457033504141116						01 00 00		9
090000	183572	0706	100000	80000	183572		183572	11
251500713040610110707800161106015200815044508501985						01 00 00		9
100000	194970	0707	80000	120000	204203		185738	11
251510813040730110708800135076017700393017306581172						01 00 00		029
130000	183572	0708	120000	140000	183570		183572	11
251520913040870110709800115076015100600023307821600						01 00 00		9
115000	183843	0709	140000	90000	184387		183300	11
251531013040960110710800189111017000576037003611930						01 00 00		9
140000	183979	0710	90000	190000	184387		183572	11
251541113041150110711800195116016800636028303652633						01 00 00		9
215000	187867	0711	190000	240000	189997		185738	11
251551213041390110712800126077016300476022502721823						01 00 00		9
170000	184655	0712	240000	100000	183572		185738	11
251561313041490110713800099055018000412031601521486						01 00 00		9

Table 4. The correlation elements for thirteen variables

Code	Characteristic	Ds	Dn	De	Dw	X_5 (reps)	X_6 (reps)	X_7 (reps)	Bt. weight	Sucrose %	impurity index	amino N	Na	K
1	DS	1.000	.181	.007	.180	.041	-.225	.044	.397	.024	.137	.123	.004	.299
2	DN		1.000	-.021	.083	.036	-.233	.047	.436	-.019	.127	.083	-.016	.290
3	DE			1.000	-.034	.196	-.038	-.026	.101	-.019	.046	.026	.036	.096
4	DW				1.000	-.096	-.073	.081	.165	.089	.036	.079	-.058	.145
5	X_5 (reps)					1.000	.473	.495	.067	-.241	.313	.434	.367	.093
6	X_6 (reps)						1.000	.484	-.210	-.415	.401	.400	.579	.037
7	X_7 (reps)							1.000	.019	-.428	.507	.434	.460	.346
8	Bt. weight								1.000	.074	.114	.024	-.031	.492
9	sucrose %									1.000	-.829	-.396	-.755	-.452
10	impurity index										1.000	.685	.824	.722
11	amino N											1.000	.438	.343
12	Na												1.000	.400
13	K													1.000

Table 5. Simple regression coefficients and multiple correlation coefficients

Variable code	Characteristic	Coefficients								
		b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	R^2
8	Beet weight	-49.42	164.00	202.07	52.06	169.19	44.80	-44.21	-9.42	.32
9	Sucrose percentage	14.44	-0.12	-0.24	-0.16	1.05	0.28	-0.88	9.89	.26
10	Impurity index	484.73	78.94	76.41	38.41	125.55	-25.03	152.31	175.50	.35
11	Amino N	159.69	31.70	23.68	0.75	58.36	51.03	63.12	43.65	.31
12	Na	663.81	63.71	49.93	37.81	-124.48	-6.16	306.33	126.66	.40
13	K	812.80	234.62	236.34	141.28	138.45	-158.14	50.47	373.68	.28

Table 6. Regression analysis of variable 8 (bt. weight) and 10 (impurity index)

Code	Source	$Df_{(1)}$	$Df_{(1)}$	$M.S._{(1)}$	$M.S._{(2)}$	F(1)	$F_{(2)}$
1	Ds	1	1	2535848.7	587496.1	22.6**	7.8**
2	Dn	1	1	3746045.4	535570.2	33.4**	7.1**
3	De	1	1	256862.5	139820.3	2.2	1.8
4	Dw	1	1	242783.2	5535.3	2.1	0.07
5	X_5 (reps)	1	1	124966.9	39012.5	1.1	0.51
6	X_6 (reps)	1	1	120209.5	1426228.1	1.0	19.0**
7	X_7 (reps)	1	1	5566.8	1931471.8	0.05	25.9**
	Model	7	7	1513026.7	1147262.5	13.5**	15.3**
	Error	202	202	112028.3	74796.4		
	Total	209	209	158951.7	110716.3		

$F(202,1;\ .05) = 3.89$
$F(202,1;\ .01) = 6.76$
$F(202,7;\ .05) = 2.05$
$F(202,7;\ .01) = 2.73$

SUMMARY

By looking at Table (4) which contains the correlation elements, we see that the measures of correlation are low. In other words, the degree of association among the variables are very low. However, among the above correlation elements the effect of independent variables (1) and (2) which are the distances within the row on the weight, impurity index, and K is higher than the other two distances (between the rows). The multiple correlation index R^2 which is the following ratio:

$$R^2 = \frac{\text{sum of squares due to regression}}{\text{corrected sum of squares}}$$

and reflects "the goodness of the fit" are very low. The maximum multiple correlation index for variable (8) weight, is .32. Considering the mean squares, the variables (1) and (2) (within the row) are highly significant, whereas, the others are not significant. Also considering the mean squares of variable 12, the within the row distances are significant, and between the row distances are not significant.

As a whole, in this experiment the within the row distances are significant for almost all measurements.

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