Correlations of Pre-Harvest Samples and Cultural Practices With Final Yield and Quality of Sugar Beets[1]

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A method for taking pre-harvest samples as an aid for estimating the tonnage and sugar content of the sugar beet crop in The Great Western Sugar Company territory has been devised and described by Brewbaker and Bush (1) (2) (3)[3]. Samples are taken the first week in September and again the third week of the same month by this method. Each sample consists of 10 feet of row taken at random for each 90 acres of beets being grown in a factory district. This method has been used each year since its innovation and the results obtained have led to highly accurate estimates of the amount of sugar to be produced.

Seven years ago The Great Western Sugar Company decided to obtain information relative to the effect different cultural practices might have on the beet crop. The study pertained to those farms chosen for the regular pre-harvest sampling. The information was obtained through a questionnaire which was especially designed so that the information could be readily recorded on IBM cards. This provided for a rapid analysis of relationships existing between the various practices. Many questions were answered in a categorical form while actual results were recorded in some cases.

In 1957, the pre-harvest sampling idea was extended to include an early pre-harvest sample taken about July 25. This sample was taken according to the same procedures employed in taking the regular September pre-harvest samples, except that no sugar analyses were made and both root and top weights were taken in July.

Data have been recorded from approximately 2500 farms represented by all fieldman in the Great Western organization and calculations were performed at the Colorado State University Statistical Laboratory.

For the purposes of this study, the territories served by The Great Western Sugar Company have been divided as follows:

[1] The writers are indebted to Western Data Processing Center at UCLA for the use of their computing facilities in analyzing the data.

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[3] Numbers in parentheses refer to literature cited.

Area 1, Northern Colorado; Area 2, Northeastern Colorado; Area 3, Nebraska; Area 4, Montana and Wyoming; Area 5, Ohio.

No attempt will be made here to discuss all of the studies which are possible from such a questionnaire; only some of the results which may be of general interest will be presented. Further, only 1960 results will be discussed except for few occasions where the years 1957-1960 were combined for a total effect.

It must be emphasized that these results are based on agricultural practices under wide-scale field conditions and a wide range of management levels. They do not represent basic agronomic relationships, but indicate results and conclusions that can be obtained from farm practices, as indicated by the characters which can be, at least, partially measured.

In making a study of this type the experimenter is faced with several unavoidable complications. There is no way of measuring the effects of weather, sugar beet diseases and insects. Without these complications the results presumably would be more accurate or would show greater significance.

Yield-Stand Relationship

One of the more interesting graphs plotted from the results of the survey deals with the effect thinning methods may have on the final stand, the 1960 results being presented in Figure 1. It

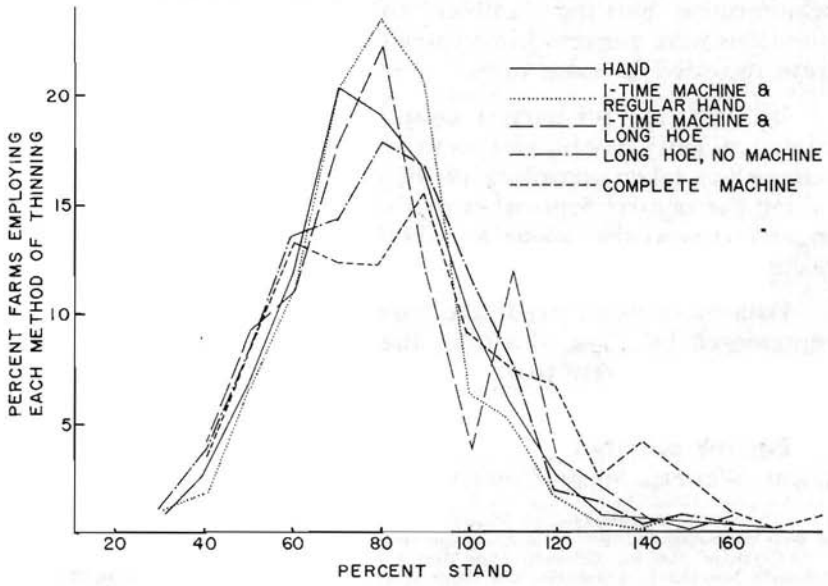


Figure 1.—Total Great Western district, 1960—method of thinning and resulting stand.

is apparent that all thinning methods gave essentially the same final stand except for small deviations in one time machine followed by long-handle hoes and complete machine. The fact exists that less than 5.5% of the farms used complete machine, while over 60% used hand thinning.

The relation of stand to final yield is presented in Figures 2, 3, 4, 5, for Areas 1, 2, 3, and 4. Here the predictions are calculated from regression equations and steady increases in percent stand are accompanied by increases in yield. Maximum yields are obtained at approximate stands of 150 beets per 100 decrease. Insufficient data are available beyond this point for adequate analysis.

Yield Predictions

Correlations between final yield of beets and weight of roots at the various pre-harvest dates are presented in Table 1. Computing on a linear basis, the final yield will be 14.84 tons per acre plus an additional 0.2633 ton for each ton of the early September sample.

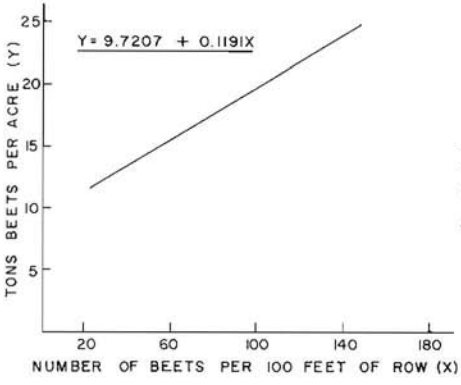


Figure 2.—The Great Western Sugar Company, 1960—Area 1.

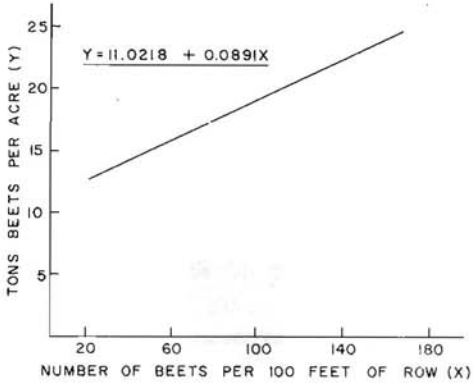


Figure 3.—The Great Western Sugar Company, 1960—Area 2.

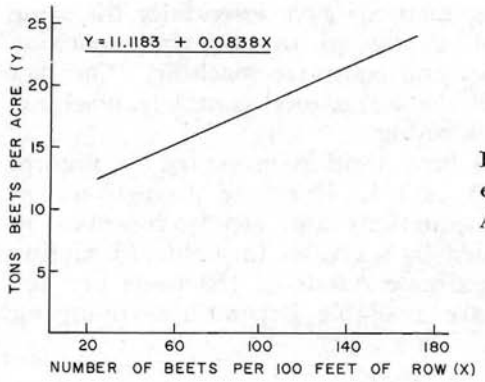
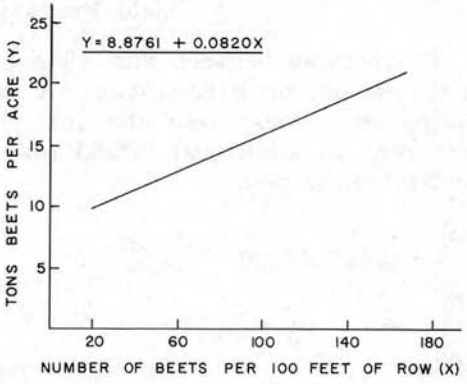


Figure 4.—The Great Western Sugar Company, 1960—Area 3.

Figure 5.—The Great Western Sugar Company, 1960—Area 4.



As would be expected the correlation between September root yield and the final yield is significant. The relationship (significant at the 5% level) between weight of tops in July and final yield of beets is also given in Table 1. It is quite possible, since this high correlation exists, that top weights taken in July might be substituted for the second September sampling as a predicter of final yield. A prediction from this sample, if satisfactory, would be much more useful because it is taken earlier.

Sugar Content Predictions

The correlations between the sugar content indicated by the preharvest samples and final results appear in Table 1. The correlation coefficients are high enough to indicate that a fairly accurate prediction as to the final sugar content can be obtained through the use of this type of data.

Effects of Fertilizer Practices by the Farmer

The effects of fertilizers, as applied by the farmer, on sugar content and purity are shown by the simple correlation coefficients and coefficients of multiple determination in Table 2.

TABLE 1

RELATION — Average of Areas 1, 2, 3, 4[1]	r	b_{yx}	Predictor equation
1. Wt. of beets in early Sept. (X) to final yield of beets (Y)	0.3079	0.2633	Y = 14.838 + 0.2633X
2. Wt. of beets in late Sept. (X) to final yield of beets (Y)	0.3764	0.3210	Y = 12.743 + 0.3210X
3. Wt. of tops in mid-July (X) to final yield of beets (Y)	0.3878	0.2627	Y = -18.241 + 0.2627X
4. Sugar content in early Sept. (X) to final sugar content (Y)	0.4256	0.2831	Y = 13.761 + 0.2831X
5. Sugar content in late Sept. (X) to final sugar content (Y)	0.5032	0.3670	Y = 12.174 + 0.3670X

[1]Except for relations 4 and 5 which is the average of Areas 1, 2, and 3 only.

TABLE 2.—Current crop, areas 1, 2, 3.

Year	Fertilizer	Simple Correlation Coefficients	
		% Sugar	% Purity
1960	N	-0.1147	-0.1023
57, 58, 59, 60	N	-0.0621	-0.0917
1960	P_2O_5	0.0094	0.0224
57, 58, 59, 60	P_2O_5	0.0123	-0.0094
1960	K_2O	-0.0857	-0.1143
57, 58, 59, 60	K_2O	-0.0738	-0.0754
	Coef. of Multiple Determination (R^2)		
	Tons/Acre		
1960	N, P, K	0.0439	0.1336

Simple correlations (r) between the various fertilizer elements with both sugar content and purity have been calculated, first as fertilizers applied in 1960 and secondly by combining all years over which the study was made and by combining Areas 1, 2, and 3. The amounts of fertilizers applied to the crop are calculated from both commercial fertilizers and organic manures.

The correlation coefficients all appear non-significant—basing significance on coefficients of 0.15 or greater—and in the cases of N and K_20 are negative, indicating a slight decrease in sugar content and in purity. Considering a coefficient of multiple determination value (R^2) of .04 or greater as significant for a sample of this size it was found that these values are significant. These coefficients give us the estimated percent decrease in variance in predicting percent sugar and purity given the factors N, P, K and final yield on which to base our predictions. In the case of predicting sugar, the variance is decreased by 4% and by 13%

in predicting percent purity. In evaluating these data it should be kept in mind that only a narrow range of fertilizer applications is represented. For example, nearly 50% of the farmers applied between 50 and 100 lbs of N per acre and over 45% of the farmers applied between 50 and 100 lbs of P_2O_5, whereas less than 3% failed to apply either of these fertilizers. Nearly 50% of the farmers did not apply K_2O.

The coefficient of multiple determination indicates a combined improvement in both sugar content and purity, thus meaning that the present farm fertilizer practices are nearly correct. However, the application of an additional amount of fertilizer might be safe without affecting the quality of the beets.

Some Indications from the Statistical Analysis of Data Taken from Pre-Harvest Sample Studies 1960

Results

1. Contrary to results observed in controlled experiments, fertilizers appeared to have little or no effect on yield, percent sugar, or percent purity. The fertilizer effects are at least partially masked by the random uncontrolled variables such as management, weather and native fertility. The fact that a few of the farmers did not apply some fertilizers may have had a profound effect on the statistical analysis.

2. Percent stand shows a positive, constant, independent, significant effect on yield. The effect of percent stand on percent sugar shows a positive, significant effect, this effect being much smaller than that on yield.

3. The weight per sample, taken September 4 as the first pre-harvest sample is highly associated with final yield and is valuable in predicting final yield. The sampling error for these ten-foot samples is large and the result is lower correlation values. The logical assumption is that the yield prediction should be better for samples taken closer to the time of harvest. Thus the second pre-harvest sample taken the third week of September shows a greater correlation between sample weight and final yield.

Discussion

The data recorded on the "Pre-harvest Sample Field Data Sheet" for 1960 have been stored on IBM punch cards and a preliminary report of some of the results has been made.

Both simple and multiple correlations have been calculated for certain factors, the results of which are herein discussed.

As these results are considered, it must be realized that they are for only one year's data and in some cases the number of observations is too low for accurate conclusions to be drawn for

a study of this type. Also, a high standard error must be assumed for each figure, as reported. Some conclusions are indicated which apply to the different areas in which the Great Western territory has been divided for this study. These areas being: northern Colorado (Brighton, Eaton, Fort Collins, Greeley, Longmont, Loveland, and Windsor); northeastern Colorado (Brush, Fort Morgan, Ovid, and Sterling); Nebraska (all Nebraska factories and Wheatland, Wyoming); Billings-Lovell; and Ohio (Fremont and Findlay).

In all of the studies herein discussed, fertilizers N, P_2O_5, K_2O and certain other variables are combined to show their multiple effect on final tonnage, sugar content, and purity. These are compared with simple correlation values for each of the variates.

The following relationships are discussed concerning Areas 1, 2, 3, and 4 (with the omission of relationship three from Area 4). Discussion of these relationships for Ohio Area will be omitted because of an insufficient amount of data for this study.

1. N, P, K, %Stand with Final Tons Beets per Acre
2. N, P, K, %Stand with Final %Sugar
3. N, P, K, %Stand with Final %Purity
4. N, P, K, Tons Beets/Acre 1st Sample with Final Tons Beets/Acre
5. N, P, K, %Sugar Sept. 4 with Final %Sugar

N. P. K. %Stand- -Tons per Acre

NORTHERN COLORADO

There is a slight significant positive relationship between application of N and tons beets per acre while no significant relationship was caused by the application of P_2O_5 and K_2O in regards to yield of beets. Percent stand appears to have a large effect on final yield of beets. The combined effects of N, P_2O_5, and K_2O on tons beets per acre gives a small, but positive effect which is significant. Combining the fertilizers with percent stand gives a large correlation ($R = 0.5299$) that definitely shows percent stand is a deciding factor in determining tons per acre and that it is also independent of fertilizers.

NORTHEASTERN COLORADO

In the single comparisons N and K_2O have a significant positive effect on tons per acre, whereas P_2O_5 shows a positive but non-significant effect.

There is a non-significant negative relation of fertilizers with percent stand in the single comparisons but a highly significant effect of percent stand on tons per acre.

The combined effects of N, P_2O_5, K_2O and percent stand on tons per acre is indicated by a significant correlation which leads to the same conclusions as that for Northern Colorado.

NEBRASKA

The single comparisons show a positive significant effect on yield. These comparisons also show that the fertilizers do not have a significant relation with percent stand.

The combined effects of the fertilizers and percent stand show a significant effect on tons per acre with a multiple correlation of 0.5846.

N, P, K, %Stand--%Sugar

NORTHERN COLORADO

From single comparisons of the fertilizers to percent sugar, there appears to be a non-significant negative effect. Percent stand shows a significant but small effect on percent sugar.

The fertilizers combined with percent stand have a positive significant effect on percent sugar.

NORTHEASTERN COLORADO

The single comparisons show that the fertilizers have a negative non-significant effect on both percent stand and percent sugar, and percent stand has a significant effect upon percent sugar.

When percent stand is included in the analysis with the fertilizers, the effects of the fertilizers are changed very little and the multiple correlation coefficient shows little significant effect on percent sugar.

NEBRASKA

The single comparisons of the fertilizers with percent sugar show that N has a positive but non-significant effect on percent sugar, whereas, P_2O_5 and K_2O show negative non-significant effects. The effect of percent stand on percent sugar is positive but shows little significance. The combined analysis of the fertilizers and percent stand with percent sugar shows a positive significant relationship and that the effect of percent stand is independent of the effect of the fertilizers.

BILLINGS-LOVELL

The fertilizers in single comparisons have positive but almost no effect on percent sugar. Percent stand also shows a positive but non-significant effect on percent sugar.

The effect of fertilizers combined with percent stand on percent sugar is positive, but insignificant.

N, P_2O_5, K_2O %Stand—%Purity

NORTHERN COLORADO

The fertilizers in single comparisons have a negative effect on percent purity, whereas, percent stand shows a positive but non-significant effect.

In combining the fertilizers and percent stand it is found that they have a positive significant effect on percent purity.

NORTHEASTERN COLORADO

Here again the fertilizers have a negative non-significant effect on percent purity. The fertilizers also have a negative effect on percent stand but there is no significant effect for any of the fertilizers in this comparison.

The effect of the fertilizers on percent purity increases when combined with percent stand. The multiple correlation coefficient appears to be significant when combining all of the above factors.

NEBRASKA

The fertilizers show a negative effect on percent purity but only in the case of K_2O is there any significance. The single comparisons also show that percent stand has a small positive effect on percent purity.

The combined effects of the fertilizers with percent stand on percent purity show a positive effect with a multiple correlation of 0.4407.

N, P_2O_5, K_2O, Weight per Beet (1st PHS)[1], Final Yield

NORTHERN COLORADO

In the single comparisons, fertilizers show a positive but non-significant relationship to weight per beet in early sample and to final sample weight.

The effect of weight per beet (1st PHS) on tons per acre is significant and increases in relationship from pre-harvest sample to final yield.

The multiple comparison shows that a significant relationship exists.

NORTHEASTERN COLORADO

In single comparisons N and K_2O appear to have a significant effect on weight per beet (1st PHS), whereas, P_2O_5 shows no significance on weight per beet. In this comparison, weight per beet has a significant effect on tons per acre. When the weight per beet is combined with N, P_2O_5, K_2O in the analysis the effect on tons per acre is highly significant, $R = 0.5046$.

[1] 1st PHS refers to pre-harvest sample taken in early September.

NEBRASKA

The single comparisons show that there is no significant relationship between fertilizers and weight per beet but that weight per beet has a significant positive effect on final tons per acre. This effect holds in the combined analysis of N, P_2O_5, K_20 and weight per beet (1st PHS) to tons per acre.

BILLINGS-LOVELL

The fertilizers appear to have no significant effect on weight per beet, however, weight per beet (1st PHS) appears to have a significant effect on final yield.

The combination of these factors also shows a positive sig- per beet, however, weight per beet (1st PHS) has a significant effect on final yield.

N, P_2O_5, K_20, %Sugar (1st PHS)—Final %Sugar

NORTHERN COLORADO

The effect of fertilizers on percent sugar (1st PHS) appears to be negative and non-significant and their effect on final percent sugar is negative but appears to have a significant relationship. The percent sugar (1st PHS) appears to give a good prediction of final percent sugar and is independent of fertilizers.

NORTHEASTERN COLORADO

The single comparisons show that the fertilizers have a negative significant effect on percent sugar (1st PHS) and final percent sugar. However, percent sugar (1st PHS) is a good predictor of final percent sugar.

The fertilizers combined with percent sugar (1st PHS) have a positive significant relationship to final percent sugar. Percent sugar (1st PHS) also appears to be independent of the fertilizers.

NEBRASKA

The single comparisons show that fertilizers have no significant effect on either percent sugar (1st PHS) or final percent sugar and that the relationship between percent sugar (1stPHS) and final percent sugar is highly significant. The combined effects of fertilizer and percent sugar (1st PHS) on final percent sugar appear to be highly significant with percent sugar from the preharvest sample being the most dominant factor.

BILLINGS-LOVELL

The effect of fertilizer on percent sugar (1st PHS) appears to be greater than the effect of fertilizers on final percent sugar. However, percent sugar (1st PHS) appears to have a significant relationship to final percent sugar.

The correlation between percent sugar (1st PHS) and final percent sugar is almost as large as that of the combined effects of fertilizers and percent sugar (1st PHS) on final percent sugar. This indicates that fertilizers have relatively no effect on final percent sugar.

Summary

Prepared for The Great Western Sugar Company Managers

1. Perhaps because of the narrow range of fertilizer applications as observed in these studies, fertilizers appear to show little or no effect on yield, percent sugar, or percent purity. For example, over 50% of the farmers applied between 50 and 100 lbs of N per acre with very few applying amounts which might be considered excessive and only a small number of farmers not applying any fertilizer.

Their results lead to the conclusion that the present farm fertilizer practices are nearly correct, although it might be safe to use a small additional amount of N fertilizer, if applied early in the season, without materially affecting beet quality.

2. Percent stand shows a positive effect on yield with maximum yields obtained from approximately 150 beets per 100 feet of row.

3. Results from early September sampling give a good prediction of final yield and sugar content, but the later September sampling taken closer to final harvest, gives a slightly better prediction than the early sample.

However, a slightly higher correlation was found between top weight in July and final yield than was obtained between September beet weights and final yield. This indicates that a satisfactory yield estimate can be made from July top weights.

Regression formulae for calculating predicted yields from samples taken at the various dates are presented.

References

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