# Effect of Soil Physical Condition and Fertility on Yield of Sugar Beets on a Brookston Clay Soil

E. F. BOLTON AND J. W. AYLESWORTH[1]

*Received for publication May 5, 1967*

## Introduction

Earlier investigations with sugar beets indicated that improved soil physical condition, as evaluated by increased soil pore space, was an important factor in the production of this crop. The soil physical factor was shown to be especially significant in fine textured soils of level topography in which drainage was frequently inadequate. Favorable porosity ranges, required to meet growth requirements of sugar beets and other crops, were evaluated by Baver (1)[2] for the clay soils of northwestern Ohio. In addition, it was concluded that good soil physical condition was essential for efficient fertilizer use.

Smith and Cook (7) also related improved soil physical condition to yield increases of sugar beets. Their work further pointed to the benefit of the improved aeration that was associated with better oxidizing conditions in the soil.

The relative importance of soil physical condition and fertility for sugar beets was further investigated following the introduction of soil conditioning agents. Improvement of soil physical condition by synthetic materials did not consistently increase yield of sugar beets (2, 3) while increased use of fertilizer, especially nitrogen, increased yield greatly (8).

Fine textured soils with level topography constitute the predominant acreage of southwestern Ontario and historically have been described as "problem soils" in regards to crop production. Nevertheless, high fertilizer applications to such soils have given large increases in yields of sugar beets similar to increases reported from other areas. This favorable effect of fertilizer was evident for corn under pore space conditions associated with continuous row cropping and the effect was not enhanced by increasing the soil pore space. However, similar information was not available for the sugar beet crop on this soil. Because sugar beet acreage was expanding on the fine-textured soils of this region, it was necessary to determine the significance of improved soil physical condition to this crop when fertility was adequate in accordance with soil test recommendations.

---

[1] Research scientist and officer-in-charge, respectively, Soil Substation, Research Branch, Canada Dept. of Agriculture, Woodslee, Ontario, Canada.

[2] Numbers in parentheses refer to literature cited.

## Materials and Methods

An experiment was established on Brookston clay soil at Woodslee to determine the effect of improved soil physical condition in combination with the fertility factor for growth and yield of sugar beets. The experimental area had been heavily row cropped prior to establishment of the experiment. The soil was well supplied with potassium on the basis of soil test and moderately well supplied with phosphorus and nitrogen. The area was drained with tiling spaced 50 feet apart.

The experiment included two levels of soil physical condition with each level established alone or in combination with three levels of fertility. The improved soil physical condition was effected by incorporation of VAMA soil conditioner at 0.01% concentration within the 0-6 inch depth in 1960. The unimproved condition was the result of the cropping history of the site. Fertility levels included the level inherent from the previous cropping system in comparison with a medium fertilizer application of 30 pounds N, 40 pounds $P_2O_5$ and 20 pounds $K_2O$ and a high application of 90 pounds N, 120 pounds $P_2O_5$ and 60 pounds $K_2O$ per acre. The fertilizer treatments were repeated each year. Results for the check and high fertility levels only are reported.

The plots were 25 feet square and the experiment was replicated four times in a randomized block design. Monogerm seed was planted each year as early as soil and weather conditions permitted. A spray program was followed to control insects and diseases.

Effect of treatment was evaluated by measurement of root yield, gross sugar yield, percent sucrose and percent apparent purity. Average weight per beet, top yields and plant emergence were also measured.

The degree and duration of soil physical improvement achieved by addition of VAMA was determined by soil porosity measurement. Core samples were obtained for this purpose soon after emergence each year.

## Results

Sugar beet root yield was higher or tended to be higher on the conditioner-amended soil in comparison with the check yield in all years except in 1965 (Figure 1). The high fertility level increased root yield every year. Each year, the largest root yield increase resulted where conditioner was combined with high fertility. The effect of high fertility combined with improved physical condition appeared to be additive.

Gross sugar yield followed the pattern established for root yield (Figure 2). Increased yields or trends toward increased

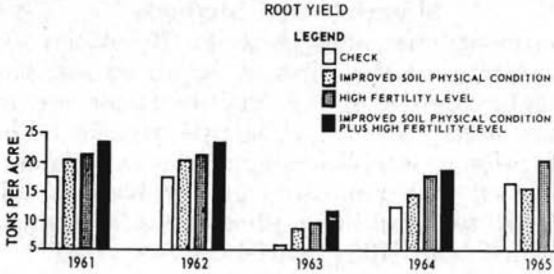


**Figure 1.—Effect of soil physical amendment and fertility level on sugar beet root yield. The LSD values at the 5% level of significance are 3.03, 2.78, 2.10, 3.11 and 1.51 tons per acre for the years 1961-65, respectively.**

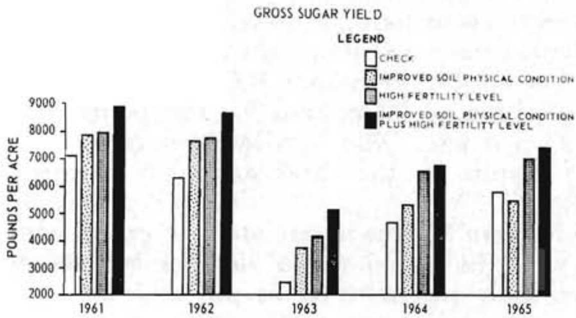


**Figure 2.—Effect of soil physical amendment and fertility level on gross sugar yield. The LSD values at the 5% level of significance are 1090, 1200, 870, 1140 and 1000 pounds per acre for the years 1961-65, respectively.**

yield were associated with conditioner treated soil in all years except 1965. The high fertility level, alone, significantly increased gross sugar yield in all years except 1961. Fertilizer application combined with the physical amendment produced the maximum gross sugar each year, and again, the influence appeared to be additive.

Root size (Figure 3) appeared to be the plant characteristic most closely associated with gross sugar and root yields . Average weight per beet was higher or tended to be higher on the amended soil in all years except 1965. The high fertility level also increased beet size and, again, a combined influence of fertility and improved tilth was evident in the first four years.

Weight of sugar beet tops at harvest was increased each year at the high fertility level but there was no additional increase in top weight where fertility was combined with the

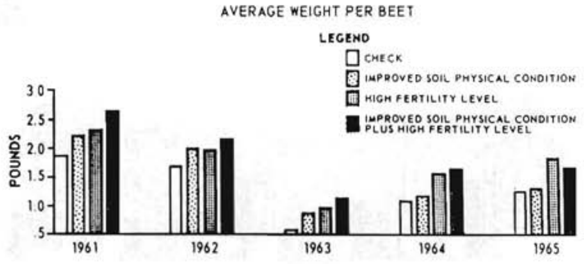


**Figure 3.—Effect of soil physical amendment and fertility level on average weight per beet. The LSD values at the 5% level of significance are .31, N.S., .20, .23 and .21 pounds per beet for the years 1961-65, respectively.**

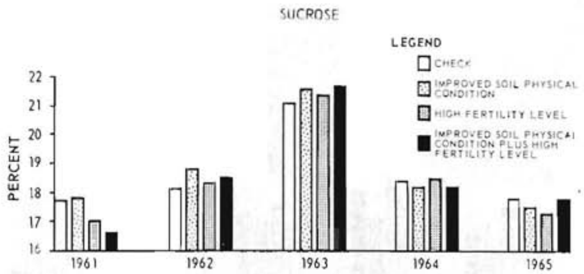


**Figure 4.—The effect of soil physical amendment and fertility level on percent sucrose. The LSD values at the 5% level of significance are .8, .2, N.S., N.S. and N.S. percent sucrose for the years 1961-65, respectively.**

VAMA treatment. In addition, the amended soil alone did not increase top yield.

Percent sucrose (Figure 4) was reduced by high fertility in 1961 but did not appear to be affected by fertility or conditioner amendment in the other years. A very high sucrose concentration occurred in 1963 when root yields were low because of a dry season. High fertility also reduced percent apparent purity (Figure 5) in 1961 and resulted in a similar trend in 1962.

Conditioner amended soil, alone or combined with high fertility, was associated with improved emergence in 1962. There were no significant differences due to treatment in other years, although trends toward increased emergence were apparent in 1963 and 1965 on conditioner treated soil. Emergence was quite adequate each year on all plots to permit thinning plants to a constant spacing of one per foot within the row.

The soil physical condition was improved by conditioner application, on the basis of pore-space measurements on treated

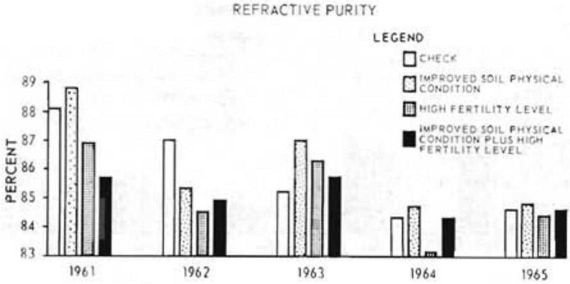


**Figure 5.—The effect of soil physical amendment and fertility level on percent apparent purity. The LSD values at the 5% level of significance are 1.8, N.S., N.S., N.S. and N.S. percent apparent purity for the years 1961-65, respectively.**

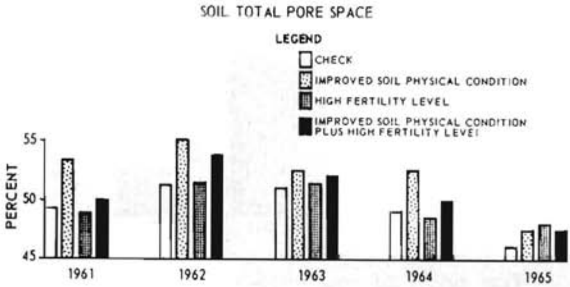


**Figure 6.—The effect of soil physical amendment and fertility level on soil total pore space. The LSD values at the 5% level of significance are 1.9, 3.0, 1.6, 2.2 and N.S. percent total pore space for the years 1961-65, respectively.**

compared with untreated plots (Figure 6). At the low fertility level, the amended soil had greater total pore space than the check treatment during the first four years following application. At the high fertility level total pore space on the amended soil was significantly greater than on the check treatment in 1962 and trends towards increased pore space were apparent in other years. Increased effectiveness of conditioner in the absence of applied fertilizer has also been noted by Martin (4).

Soil physical amendment increased average soil total pore space for the 1961-65 period (Table 1) and resulted in higher average root yield, gross sugar and root size. The high fertility level which did not affect soil pore space also increased average yield, gross sugar and root size. The largest effect on average yield values resulted where improved soil physical condition was combined with high fertility. Soil amendment did not significantly affect average percent sucrose and apparent purity although a trend toward reduced purity resulted at the high fertility level.

**Table 1.—Effect of soil physical and fertility amendment of a Brookston clay on average sugar beet yield and soil total pore space for the 1961-65 period.**

| Soil treatment | Root yield tons/Acre | Gross sugar lbs/Acre | Weight per beet lb | Sucrose % | Apparent purity % | Soil total pore space % |
|---|---|---|---|---|---|---|
| Check | 14.47 | 5,270 | 1.29 | 18.6 | 85.8 | 49.3 |
| Improved soil physical condition | 16.34 | 6,030 | 1.50 | 18.8 | 86.1 | 52.2 |
| High fertility level | 18.58 | 6,720 | 1.72 | 18.5 | 85.0 | 49.6 |
| Improved soil physical condition plus high fertility level | 20.54 | 7,430 | 1.84 | 18.5 | 85.0 | 50.8 |
| LSD (0.05) | 1.08 | 440 | .11 | .3 | .9 | .9 |

## Discussion

The results indicated that amendment of Brookston clay soil with a synthetic conditioner (VAMA) effectively increased yield. An adequate fertilizer application without the conditioner amendment produced yields that were as high or higher than those occurring where conditioner had been incorporated alone. A combination of conditioner amendment with high fertility, however, was shown to produce a yield that was additive with respect to both physical and fertility factors. Size of sugar beet root, associated with soil treatment, was closely related to sugar yield.

Sugar beet quality as reflected by percent sucrose and apparent purity, was not greatly affected by fertility level or conditioner amendment, although reductions or trends were observed in two seasons at the high fertility level. Concurrent fertility studies on this soil have indicated that nitrogen applications in excess of that used in this experiment decreased quality and sugar yields.

Soil physical condition was improved by the conditioner application, at least for the first four years based on pore-space measurements. The increase in total pore space achieved by treatment was equivalent to the increase effected by grass or legume crops (5) in other experiments.

These results emphasize the importance of maintaining a favorable soil physical condition for sugar beet production on Brookston clay soil. The data further indicate that the benefits of recommended fertility practices are enhanced by an improved level of physical condition. It is suggested that improvement of soil physical condition is more important in sugar beet production on Brookston clay than on many soils where studies (2, 8) have indicated that fertility alone was the predominant requirement. Although fertility level was an apparent limiting factor in some of the earlier soil physical investigations (1) where low yields were obtained, the present data indicate that physical condition is an important factor for Brookston clay under favorable fertility conditions.

## Summary

The effect of soil physical improvement on sugar beet yield and quality was investigated in a field experiment on a Brookston clay soil. Soil physical improvement, affected by soil conditioner application, was compared with a check treatment and each level of soil physical condition was established at a low and high fertility level.

Improved soil physical condition, at both fertility levels, resulted in larger roots and in higher root and sugar yields. The effects of physical improvement and fertility were additive. Results emphasized the importance of providing a high level of physical condition along with adequate fertility on the Brookston clay soil.

## Acknowledgment

We wish to thank the staff of the Biographic Unit, Canada Department of Agriculture, Ottawa, for preparation of the graphs.

### Literature Cited

(1) BAVER, L. D. and R. B. FARNSWORTH. 1940. Soil structure effects in the growth of sugar beets. Soil Sci. Soc. Am. Proc. 5: 45-48.

(2) HAISE, HOWARD R., L. R. JENSEN, and JOSEPH ALESSI. 1955. The effect of synthetic soil conditioners on soil structure and production of sugar beets. Soil Sci. Soc. Am. Proc. 19: 17-19.

(3) MARTIN, W. P., G. S. TAYLOR, J. C. ENGIBOUS and E. BURNETT. 1952. Soil and crop responses from field applications of soil conditioner. Soil Sci. 73 :455-471.

(4) MARTIN, W. P. 1953. Status report on soil conditioning chemicals I. Soil Sci. Soc. Am. Proc. 17: 1-9.

(5) PROGRESS REPORT. 1947-1953. Dom. Expt. Substation, Woodslee, Ont. 25-27.

(6) RICHARDS, N. R., A. G. CALDWELL and F. F. MORWICK. 1949. Soil survey report No. 11, Ontario Agr. Coll., Guelph, Ont.

(7) SMITH, F. W. and R. L. COOK. 1946. The effect of aeration, moisture and compaction on nitrification and oxidation and the growth of sugar beets following corn and legumes in pot cultures. Soil Sci. Soc. Am. Proc. 11: 402-406.

(8) STOCKINGER, K. R., A. J. MACKENZIE and E. E. CARY. 1963. Yield and quality of sugar beets as affected by cropping systems. J. Am. Soc. Sugar Beet Technol. 12: 492-496.