Trends in Sugar-Beet Field Machinery Development

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This paper is based upon a critical review of machinery development during the past 30 years for planting, blocking and thinning, and harvesting of sugar beets. The sugar beet is a root crop grown on a field scale now totaling more than 1 million acres annually. The tonnage of the harvested crop exceeds 10,000,000 tons. It is a low-growing plant requiring much heavy hand labor for thinning, blocking, and harvesting.

For many years it has been the hope of growers to be able to mechanize much of the hand labor necessary to produce sugar beets, but decades of human ingenuity and effort have failed to produce field machinery for blocking, thinning, and harvesting which meets general grower acceptance. During the past 30 years, hundreds of thousands of dollars have been spent by inventors, sugar companies, and experiment stations in trying to mechanize the labor peaks coming during the blocking and thinning period and later when the matured crop is harvested. The trends discussed in this paper will be limited to the following: (1) Planting equipment, (2) blocking machinery, and (3) harvesters.

Planting Equipment

Until about 10 years ago sugar-beet seeding machinery consisted principally of fluted feed drills, either with shoe or disk-furrow openers, with the former predominating in the earlier types. These drills, still widely used, deposit a more or less continuous flow of seed into the opened furrow. The resulting stand is, of course, dependent upon the quantity and viability of the seed planted and the distribution of the seed in the row. Drilled beet seedlings rarely come up in uniform distribution but more or less in clumps of seedlings, which, by many, is believed to be a favorable factor in attaining stands under crusty conditions of soil. Such distribution of seedlings, however, contribute to more difficult thinning conditions, since more finger work is required to thin out the clumps to single seedlings.

Mervine and McBirney (5) in their studies of shoe and disk-furrow openers over a period of years accumulated data showing advantages of disk-furrow openers and these seem to be gaining in grower acceptance.

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Plate planters are now attracting more and more attention as well as favor among growers. Rassmann manufactured a hill drop planter about 1932; planters of this type are used successfully in the northern states.[2] Hill drop planters deposit seeds in checks 18 inches each way with clumps of seed varying from approximately 3 to 8 seedballs to the hill. Such planting provides for cross cultivation, but clumps of beet seedlings may require considerable finger work in thinning.

Single Seedball Planter.—The desire to thin beets mechanically by cross cultivation or by "down-the-row" devices emphasizes the need of uniform seedling distribution in the row. Mervine and McBirney (5) made many experiments with blocking devices and conducted research and development work on planting equipment to achieve better seedling distribution. In the course of their studies, each developed what has become to be known as a single seedball planter. Mervine, who had studied disk-furrow openers for planters, conceived the idea of a series of single seedball cups between the disk openers. These were arranged to receive single seedballs and drop them at regular intervals into the opened furrow. McBirney developed the chain-feed single seedball j)laiiter, in which a chain equipped with small seed cups passes through the seedbox to pick up single seedballs, and then carry these through a tube for discharge near the base of the opened furrow. Both of these designs were quite satisfactory, all hough the chain feed was slightly the more accurate. Subsequent tests by these workers, however, with a commercial plate planter with plates designed for single seedballs showed field results comparable 1o those using die more complicated mechanisms of their own design, so it was concluded that commercial plate planters equipped with single seedball plates might well be used. A number of commercial companies now provide regular single seedball plates for the conventional types of planters. Some special planters of both the cup and plate types have been manufactured and used by growers with apparent success, but none of these seem to possess any marked advantages over the more conventional commercial units.

Sheared Seed Experiment.—Single seedball planting while marking an advance in controlled seed distribution does not completely overcome the problem of multiple seedlings. The advantages of single seedlings in the row are so apparent for efficient thinning operation and particularly for mechanical thinning, that an attempt has been made to shear seedballs into segments, with the subsequent cleaning and sorting of these into single-germ segments. Bainer (2) was successful in doing this in February 1941 by various ingenious methods which included the up-grading of the seed in germination. Such

[2]Rassmann Manufacturing Company, Beaver Dam, Wisconsin.

seed shearing has been tried in Germany (3), but for some reason it has not been adapted to field practice. Bainer's (2) experiments are unusually promising, as is evidenced by his paper presented at this meeting. This sheared seed is successfully planted by special plate planters. As might be expected the number of single seedlings appearing in the drilled row is materially increased. This condition in turn contributes still further to the ultimate success of cross cultivation and row blocking, or even hoe blocking.

Thus it may be stated that the trends in planting equipment for sugar beets is toward plate planters equipped with furrow openers and with plates designed to handle single seedball and single-germ segmented seed.

Blocking and Thinning Operations

Quite naturally the urge to improve planting equipment is closely related to blocking and thinning operations. With a good distribution of single seedlings, blocking and thinning operations by mechanical methods become more practical and it is thought possible, by the more optimistic, to produce satisfactory crops with no hand-thinning work. Where flat planting is practiced, cross cultivation by using the regular beet cultivator equipped with suitable sweeps properly staggered and spaced in accordance with stand conditions as worked out by Mervine (6) represents the simplest and most practical mechanical-thinning equipment. Where ridge planting is practiced then row blocking is necessary. Row-blocking equipment has received considerable attention, but it has not met the same general success that has come from cross cultivation. The cut-out double disk, such as the E.Z. row blocker developed about 1932, did not meet grower acceptance.[3] The Uddenborg blocker developed about the same time, which used a multiple blade-revolving wheel rotating at right angles to the row, was perhaps a little more successful.[4] But this principle has only recently received favorable grower attention in a machine developed originally as a cotton blocker.[5] This unit by some reworking of knife shapes and adjustment of treads for beet work offers considerable promise as a successful row blocker. Several concerns are using this principle which seems to represent the most promising trend in row-blocking equipment.

Harvester Development

The many attempts made to develop harvesters offer a better opportunity to study the trends in development than is possible with planters and thinning equipment. On the other hand, the lack of successful field units may detract from the value of any conclusions

[3]E. Z. Manufacturing Company, Lincoln, Nebraska, 1932.
[4]Uddenborg, Rickard, Fort Morgan, Colorado, 1933.
[5]Dixie Cultivator Corporation, Dallas, Texas.

which may be reached from such a study. The large number of attempts made to develop a harvester, however, should show some common trends. In all a total of 49 units have been analyzed, covering a period from about 1910 to date. Out of these, 2 distinguishing types of harvesters are evident: (a) Those which top the beet in place and subsequently lift the root, and (b) those which first lift the beet and then remove the top as a machine operation. There were 38 of the 49 machines of the former type, and 11 of the latter. Single-row harvesters have predominated since only 3 have been 4-row units, 9 of 2-row units, and all of the remainder single row. Naturally, all of the earlier types were horse drawn, with ground-driven mechanisms. The ground-driven idea still prevails, but modern designers are leaning toward engine drives principally through tractor power take-offs.

In order to discuss the trends in harvesters, the machine elements will be taken up in the following order:

1. Preparatory mechanisms such as coulters and disks.
2. Topping mechanisms including both ground topping and machine-topping elements.
3. Plows, or lifters.
4. Elevating mechanisms.
5. Soil-beet separation.
6. Disposition of tops and beets.
7. Drive mechanisms.
8. Mountings.

The names of machines by using inventors' or company names will be used where identification of principles is merited.

Preparatory mechanisms include any device such as coulters, disks, fingers, and jointers, either used singly, doubly, or in combinations. The purpose of such devices is to prepare the beet for subsequent operations, such as: Lifting; the removal of green or dried leaves and streamers; the breaking of the soil to reduce cloddiness; the removal of soil from near the beet to permit parts of the lifting mechanisms to function more effectively, or for a combination of these purposes. Less than half of the machines studied used any form of preparatory mechanisms, there being only 19 out of a total of 49, or approximately 39 percent. Of the 26 machines developed since 1929, 11 have had preparatory mechanisms. This again represents only 39 percent. One might readily conclude from the data that such devices are of questionable value, or even unnecessary. It must be remembered, however, that many, even most of these units, have proved unfield worthy and, therefore, do not provide reliable data.

Coulters, or disks, running close to the row, tend to reduce streamer Troubles for certain types of mechanisms such as straight, fixed knives and they may reduce weed trouble. Double disks, or coulters with jointers, 1o throw the dirt away from the beets, would scorn to bo in favor if such a mechanism is used at all. Fingers to lift the green and drooping leaves may also be used. The type of lifting mechanism used of course influences the necessity for preparatory mechanisms.

Topping devices are discussed in the two general classes of: (1) Ground lopping and (2) machine topping.

Ground-topping equipment consists essentially of two controlling elements, and these may have fixed, or variable relations, with respect to one another. These are the finder and the knife. Thus if the finder is arranged to pass over the beet to sever a given or fixed thickness of material between the base of the finder and the cutting edge of the knife, it may be said to have a fixed cut. On the other hand, if these are designed for a variable relation, then it may be termed a variable-cut topper. Previous to 1929 mechanical ground toppers were almost without exception of the fixed-cut type. One developed by Dawson had a variable-cut principle but it did not meet grower acceptance.[6] Since 1929 the variable-cut principle appears in practically all promising types of ground toppers. It may be stated definitely that the development trend in ground toppers is toward the use of the variable-cut principle.

The type of finder used is extremely variable. There are 3 general types: (a) Sliding, (b) driven wheel, and (c) track.

The sliding types may be flat plate, single bar, or multiple bar. Of these types the multiple bar has been used most, yet the flat plate is a close second. The former provides for more penetration into the crown of the beet, thus contributing to more accurate gaging in topping. Finders of the sliding type all have the disadvantage of transmitting high-lateral forces to the beet in the direction of travel, thus contributing to overturning moments in the beet, which must be resisted by the soil about the root. Where beets are high, or where the soil is soft the resisting moment may be too small to maintain the beet in a vertical position thus contributing to a slanting cut through the crown or failure to top at all. Knolle (4) analyzed these forces very well in his paper published in January 1940. The single-bar finder has been used but little, due to the difficulties of centering over the beet. It does have the advantage of better penetration into the foliage which is favorable to more accurate topping.

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To overcome the problem of overturning beets, the driven-wheel finder has been rather widely used particularly in the earlier machines. Since wheels are not quickly or easily centered, rather broad-faced wheel rims have been used. These may be smooth-faced, lugged or studded-faced, and ribbed-faced. Very little success has been obtained with the smooth-faced driven wheels, since such wheels do not climb over high beets readily, and neither are they successful in transmitting the force at the rim of the wheel to the crown of the beet to offset the shearing force of the knife. This objection has been overcome to some extent by the use of lugs, or ribs on the face of the rim, but finder wheels made of multiple plates or discs apparently offer advantages since such are more frequently used. The driven-wheel finder has been used 17 times in comparison to 7 instances for some form of sliding finder. It undoubtedly has advantages over the latter type, yet the wheel surface does not form a desirable contact with the beet crown for all conditions of field topping.

Driven-tracklayer finders provide some advantage over the driven-wheel types in that a better contact can be made with the beet crown. With one exception, these have been broad tracklayers, in order to overcome the problem of crown centering. Such a finder, however, possesses some of the disadvantages of the sliding and wheel-type finders in the way of top penetration and may be even less effective in this respect than the multiple-plate wheel finder. It is of interest to note that tracklaying finders were not in use previous to 1929, which places this type among the more recent developments. During this period it has out-numbered the wheel types 3 to 2.

A more recent development has been the narrow tread, track-type finder developed by Powers *(7)* and reported at this meeting. Of necessity this typo of finder requires a centering mechanism but it represents the most accurate ground-topping device that has been developed to dale. Based upon the information obtained from this study, the track-type finder seems 1o offer advantages over other types, particularly if it can be made into a functional narrow tread and used in combination with a variable-cut mechanism.

Where machine topping is used the beet must be removed from the soil as a preliminary to top removal. In most machines this involves the control of the beet by grasping the tops between various types of conveyors usually of the chain type, which carry the beets to topping mechanisms. The Scott-Viner harvester first developed about 1930 represents, in the opinion of the author, the most practical of this general type.[7] *It* has a set of roller bars to adjust the placement of the beet to meet the topping knives. Another type of ma-

[7]Scott-Viner Company, Columbus, Ohio.

chine in which topping takes place on the machine calls for hand placement of the beet for topping through mechanically driven revolving knives or disks. These latter do not offer any great labor advantage and are rather dangerous to operate. It is apparently more difficult to gage topping as accurately with machine-topping devices than where ground topping is used.

The form of the knife or cutting mechanism used in topping is quite variable. Rotating disks operated either singly or in pairs have been used by many designers both for ground and machine toppers. Where driven-wheel finders have been used for ground topping a fixed or shear knife has been widely used. These latter may be placed to have the cutting edge at right angles to the row axis or at an angle to it. In some units a V-shaped knife is used with its point acting along the row axis. A narrow, thin knife with its edge at right angles to the row axis is used by a recent designer (Powers). Rotating disk knives have advantages in weedy fields, but where accuracy in topping and recovery of clean tops is important some form of fixed knife is preferable, yet these are more likely to clog from wet leaf streamers. Powers (8) in 1939 introduced the idea of a vibrating knife which showed great advantages in the force required to shear the crown from the root. Relatively narrow, thin knives with the cutting edge designed to overcome streamer trouble may represent a trend for ground toppers, while rotating disks operated in pairs are preferred for machine topping.

With but a few exceptions the plow or primary lifting mechanism of harvesters has been some form of double-pointed plow. These points have had various shapes, but a rather flat surface with the points curving downward so as to develop quickly an upward force to the beet by compressing the soil against the taper of the root with the approach of the plow to the beet seems to be favored. It is apparent the form or type of plow cannot be expected to be universal, since soil type and consistency as well as subsequent lifting operations must influence the form and shape of the points to be used in a particular locality. However, some form of double-pointed plow represents the general trend.

No type of mechanism has yet been developed, which under a wide range of field and soil conditions, successfully handles the beets so as to deliver these free from soil into any type of container or bin. Naturally there have been about as many different devices as machines to perform this operation, but it is possible to observe some slight trends which may have significance. The open-chain elevator used in combination with rotating screens and other types of rotating devices has been used more than any other. Under favorable soil and moisture conditions these work quite well, but in heavy dry soils the weight of earth coming up with the beets may be several times

that of the beets. Examples of the more successful of such types may be found in the Great Western Sugar Company units and the Catchpole.[8]

Various methods for final separation have been attempted, ineluding hand sorting of beets from clods, which may have merit for certain conditions, but in general the use of open-chain elevators with rotating screens does not offer promise of a complete answer. This has brought into consideration hand sorting of beets from clods by units such as reported by Armer (1) at this meeting.

Attempts to avoid the mixing of loosened beets with large quantities of earth have brought into use various forms of fingers, rotating bars, flexible rotating parts, and similar devices to throw the plow-loosened beets more or less free of the soil. Hammer Brothers about 1930 recognized possibilities in such a device; Rienks worked on a spike digger about the same time ; and Zuckerman more recently tried out a similar idea.[9] Walz was somewhat more successful and his ideas are now under commercial development.[9] Tramontini (9) conceived the idea of a vibrator lifter following the plow; more recently he has developed the roller lifter. In all of these conceptions the basic idea is to remove the beet from the soil by some form of contact with the root, rather than to handle a mass of roots and clods and then attempt to separate these ihrough screens or chain mechanisms. It is too early to state this is more than a trend as yet only partially proved, but it is a promising trend which represents recent developments. Machine-topping harvesters have an advantage over ground-topping types in thai most beets may be engaged through grasping the tops. But good tops are not always present so these machines lack universal application. The Scott-Viner, a commercial unit of this type, represents the nearest approach to a workable field unit.

The problem of top disposal by ground-topping harvesters is about worked out. Walz and Powers each have demonstrated this in their designs. At least it cannot be considered a control problem in harvester development. The final disposal of harvested beets is so closely related to dirt tare as to preclude definite trends. Where single-row harvesters are developed the delivery of beets directly to trucks is hardly feasible, since machine-field capacities of .35 to .40 acre per hour will prevail. It can hardly be expected to double this capacity with 2-row units, and moreover, design problems in multi-

[8]Great Western Sugar Company, Denver, Colorado, and William *M.* Catchpole, Stanton, Bury St., Edmonds, Suffolk, England.

[9]Hammer Brothers, Miller, Ohio; Rienks, George, Great Western Sugar Company, Denver, Colorado; Xuckernian, John, Stockton, California; Walz, Claude, Pueblo, Colorado, and John Deere Company, Moline, Illinois.

pie-row units become complicated. Therefore, the trend is toward single-row units, with possible delivery of harvested beets into field windrows, small machine bins, or field trailers. Just at present field windrowing seems to offer several advantages.

The mountings for early machines were heavy frames carried for the most part on 4 wheels. They were tongue-guided, ground-driven, single row, and horse drawn. The trend today is toward tractor-mounted equipment, with power take-off mechanisms, yet self-propelled machines are not out of the picture particularly for large multiple-row field units. The trailer unit with power take-off drive offers certain advantages, but the problem of holding these on the row is difficult.

The Future Field Harvester

Based upon this review of progress during the past 30 years, including the author's experience with experimental machines for a period of over 10 years, the following summary of trends for harvesters is submitted.

The future field harvester is most likely to be a single-row tractor-mounted unit with its mechanisms operated through a tractor power take-off. It will have hydraulic controls. It will have a ground-topping device consisting of a narrow tread, power-driven tracklayer, finders either used singly or in multiples with variable-cut mechanism, and narrow fixed knife with thin edge possibly shaped to prevent fouling. The preliminary equipment ahead of the topper will be either disks used in pairs with appropriate concavity and set to throw earth away from the beets, or coulters used in pairs with jointers to function in a similar manner.

The plow will be double point with flat-surfaced blades curving downward at the points. These points will be set to give a relatively high initial vertical lift to the topped root after which it will be engaged by a revolving or rotating element, which may be any one of several forms, to lift the beet from the soil, as free of dirt as possible, onto elevating systems for delivery into field windrows or trailers. Tops will be picked up for windrowing or bunching. The capacity of such a unit should be about 1/3 to 2/5 acre per hour. Some field scavenging will be required for all initial designs.

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