# Sugarbeet Plant Spacing—Thinning Considerations and a Space-Planter[1]

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Sugarbeet yield is greatly influenced by plant population. Planting and mechanical thinning are the major field operations which have a direct effect on plant population. This paper presents methods to obtain proper mechanical thinner settings and the design and performance of a planter which would allow fast, uniform placement of sugarbeet seeds.

*Sugarbeet Stand Establishment*

Planting to stand is the ultimate goal in establishment of almost all types of field crops. Optimum yield of sugarbeets is obtained when the plant population is approximately 25,000-30,000 plants per acre (1, 4, 5)[3].

Planting sugarbeets to stand is seldom practiced in the Mountain States. Compensation for low and variable emergence rates and weed control problems is accomplished by planting an excess number of seeds and then thinning the emerged plants to the desired stand. Efficient mechanical thinning is, however, very much related to the planting operation, thinner setting, and weed control practice.

*Mechanical Thinning*

Proper mechanical thinner setting is primarily concerned with obtaining the desired average plant spacing from a known average plant spacing. It is quite important to consider the existing plant population when setting a mechanical thinner.

Figure 1 illustrates the yield decrease expected due to low plant population obtained with improper thinner settings. The random and selective thinners were assumed to be set to thin a field from 400 plants per 100 feet of row to 120 plants. When the previously set random thinner is used on a field containing only 240 plants, population after thinning would be approximately only 72 beets per 100 feet. Figure 1 indicates a yield decrease of about six tons per acre when the population is 72 plants per 100 feet rather than 120 plants per 100 feet. When a selective thinner set to thin from 400 to 120 plants per 100

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[3]Numbers in parentheses refer to literature cited.

feet is used on a field with initially 240 plants per 100 feet, the resulting population would be 100 plants per 100 feet, representing a yield decrease of about one ton per acre.

Consideration of factors which influence plant spacing variation is also of importance. Strooker (9) reports German investigations which indicate that a high proportion of plant spacings of less than about 5½ inches has tended to have an adverse effect on yield and root quality.

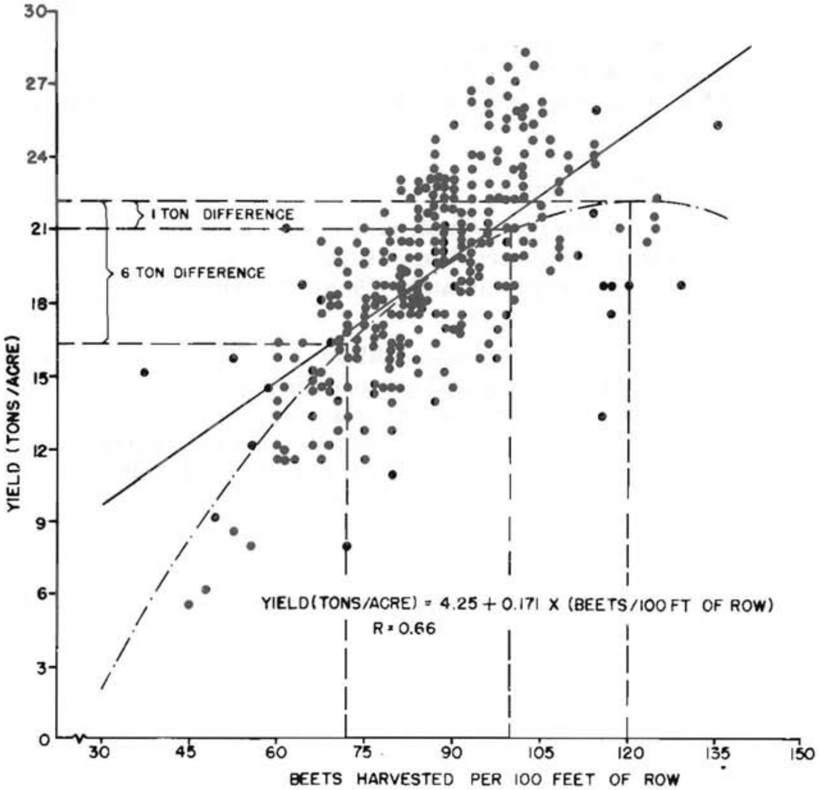


**Figure 1.—Relation between yield and number of beets harvested per 100 feet of row spaced 22 inches. Yield decrease due to improper mechanical thinner setting is shown, (broken line). R is the correlation coefficient for the linear relation. From Becker (2).**

*Prediction of Average Plant Spacing after Mechanical Thinning*

Obtaining the desired plant population from a known population by mechanical thinning is a trial-and-error process unless the relationships between initial and final plant spacings and thinner setting are considered. Assuming uniform seed spacing of 100 percent monogerm seed, Becker (1) found relationships to predict the plant spacing after mechanical thinning, if the initial plant spacing and thinner blocks cut out and skipped were known. Similarly, thinner settings can be predicted if the initial plant spacing and desired plant spacing is known.

Utilization of these equations for proper field setting of a mechanical thinner, or of the nomograph subsequently developed from them by Becker (2), is cumbersome. Therefore, a "Plant Spacing Calculator" that is easy to carry and use was developed by Jafari, Becker, and Fornstrom (6).

Figure 2 shows the "calculator" setting to thin from 400 plants to 120 plants per 100 feet of row (10 inches per plant) using a selective thinner. A 7-inch block cut out by the thinner is indicated.

Figure 3 shows the "calculator" setting when using a random thinner to thin from 400 plants (3 inches per plant) to 120 plants per 100 feet of row. A block skipped of 2 inches and a total length of block of 6.67 inches (block cut out of 4.67 inches) is indicated.

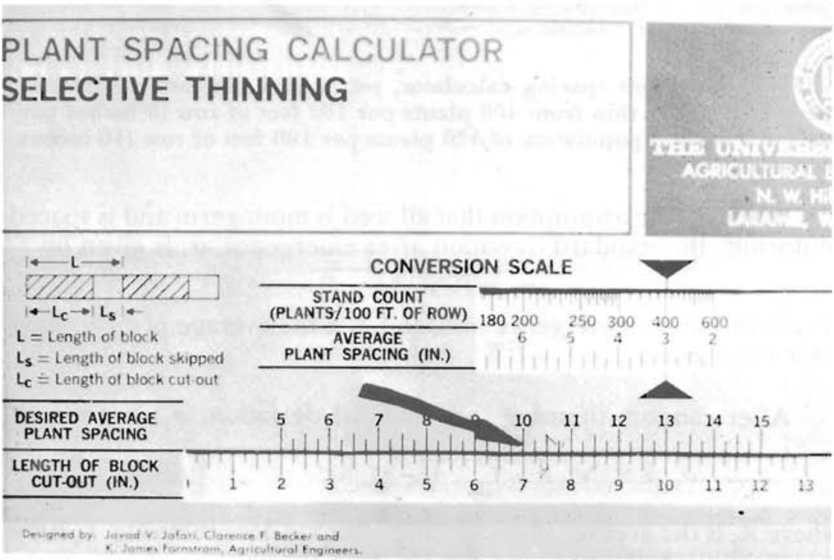


**Figure 2.—Plant spacing calculator, set to find the selective thinner setting required to thin from 400 plants per 100 feet of row to a desired population of 120 plants per 100 feet of row (10 inches per plant).**

*Additional Thinner Setting Considerations*

Along with the desired average plant spacing are other factors which should be kept in mind in order to obtain the most effective mechanical thinning results. One such factor is the dispersion of the spacings about the average spacing, *i.e.,* variation in the plant spacings. A measure of this concentration about the mean is the standard deviation.

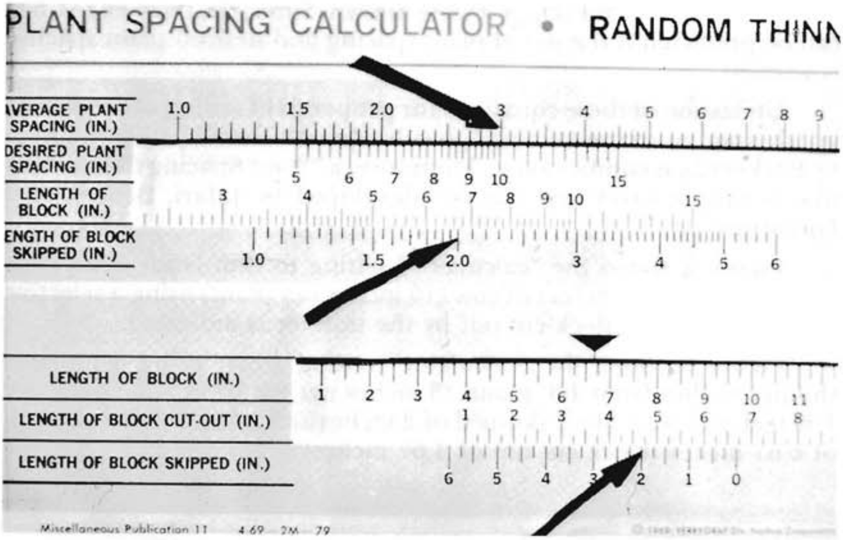


**Figure 3.—Plant spacing calculator, set to find the random thinner setting required to thin from 400 plants per 100 feet of row (3 inches per plant) to a desired population of 120 plants per 100 feet of row (10 inches per plant).**

Based on the assumption that all seed is monogerm and is spaced uniformly, the standard deviation after emergence, $\sigma$, is given by

$$\sigma = \overline{X}\sqrt{1 - E}$$

(1) where E is the emergence rate, and $\overline{X}$ is the average plant spacing after emergence.

After random thinning the standard deviation, $\sigma_r$, is given by

$$\sigma_r = \overline{X}_r \sqrt{1 - \frac{L_s}{\overline{X}}}, \quad (L_s \leq S), \qquad (2)$$

where $\overline{X}_r$ is the average plant spacing after random thinning, $L_s$ is the length of block skipped, and S is the seed spacing.

The standard deviation after selective thinning, $\sigma_s$, is given by

$$\sigma_s = \overline{X}\sqrt{2\left(2 - \frac{L_s}{\overline{X}}\right)}, \quad (L_s \leq S). \qquad (3)$$

From these expressions some thinning criteria can be inferred. Once the plants have emerged, two quantities in the standard deviation expressions are fixed, *i.e.,* the seed spacing, S, and emergence, E, which thus fix the average spacing, $\overline{X}$. The desired average plant spacing after thinning, $\overline{X}_r$ or $\overline{X}_s$, is also supposedly fixed at some desired value. Thus we are left with one thinner setting which influences the amount of variance in the after-thinning spacings, namely, the length of block skipped, $L_s$. To further simplify equations 2 and 3 we will define a new quantity:

$$C = \frac{L_s}{S}, \qquad (4)$$

which will be called the "skip ratio." With the assumption that $L_s < S$, the skip ratio, C, has an upper limit of one. Substituting C into equations (2) and (3) we have:

$$\sigma_r = \bar{x}_r \sqrt{1 - CE}, \qquad (5)$$

$$\sigma_s = \sqrt{2}\ \bar{x}\ \sqrt{(2 - CE)}, \qquad (6)$$

Figure 4 shows the relationship for the standard deviations after emergence, and after random thinning as a function of emergence

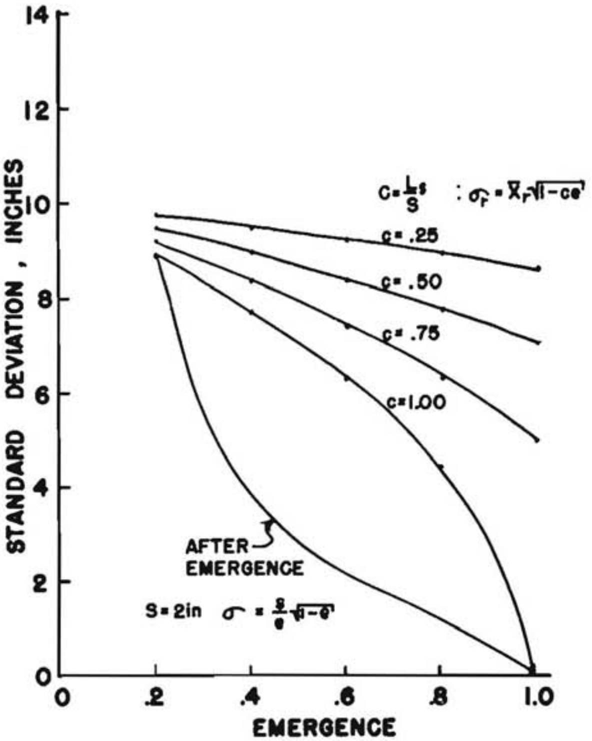


**Figure 4.—Standard deviation after emergence and after random thinning as a function of emergence rate using different skip ratios (ratio of length of block skipped to seed spacing). A seed spacing of 2 inches and a desired plant spacing of 10 inches is assumed.**

rate using different skip ratios. A seed spacing equal to 2 inches and a desired average plant spacing of 10 inches is assumed. Figure 5 shows the relationship for standard deviations after emergence and after selective thinning as a function of emergence, assuming a seed spacing of 2 inches. In general, the after-thinning standard deviations decrease as emergence increases, and as skip ratio increases. Thus, high emergence and a length of block skipped equal to the seed spacing yield the smallest deviation in plant spacings.

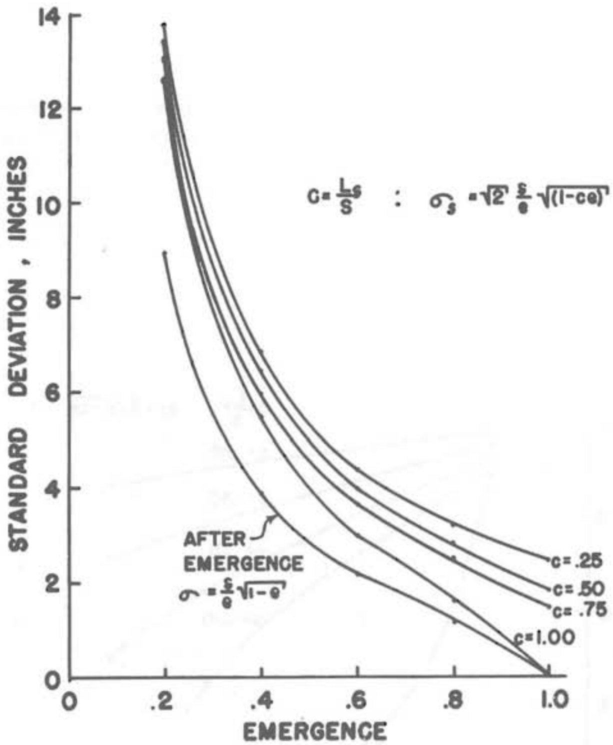


**Figure 5.—Standard deviation after emergence and after selective thinning as a function of emergence rate using different skip ratios (ratio of length of block skipped to seed spacing). A seed spacing of 2 inches is assumed.**

As an example of the effect of skip ratio, consider conditions as depicted on the graphs (Figures 5 and 6) with an emergence rate of 0.8. After emergence, the resulting average spacing is 2.5 inches and the standard deviation is 1.12 inches. Table 1 shows the standard deviations and associated probabilities for two different skip ratios. A 10 inch desired average spacing is assumed.

The results of a larger standard deviation due to skip ratios are particularly significant in the proportion of the plants which have spacings greater than 16 inches. Strooker (9) also found similar results, *i.e.*, best results were obtained when emergence was 50 percent or more and seed spacings were such that a large blade could be used in a random thinner.

**Table 1.—Standard deviations and associated plant spacings after random and selective thinning for two different skip ratios.***

| Method of thinning | Skip ratio | Length of block skipped | Length of block cut out | Standard deviation after thinning (in.) | Proportion of plants spaced over | | |
|---|---|---|---|---|---|---|---|
| | C | $L_s$ | $L_c$ | $\sigma$ | 8 in. | 16 in. | 24 in. |
| Random | 1.0 | 2.0 | 6.0 | 4.47 | 0.20 | 0.04 | 0.03 |
| Random | 0.25 | 0.5 | 1.5 | 8.94 | 0.41 | 0.17 | 0.07 |
| Selective | 1.0 | 2.0 | 6.0 | 1.58 | 0.20 | 0 | — |
| Selective | 0.25 | 0.5 | 6.0 | 3.16 | 0.45 | 0.15 | — |

*An emergence rate, E, of 0.8; seed spacing, S, of 2 inches; and after thinning average plant spacing of 10 inches are assumed.

## Planter Characteristics to Improve Stand Establishment

Thinning is not the only machine operation which influences realization of a desired plant stand. Particularly with mechanical thinning, the final stand which can be obtained is very much related to the planting operation.

One of the major assumptions involved in predicting the proper thinner setting was that the seed is evenly spaced, and that only one plant was left in a block after thinning. To keep spacing variation to a minimum, it was also recommended that the block skipped equal the seed spacing. In the practical case with present planters, the seed spacing is not uniform, and large deviations from the mean spacing are common. Figure 6 shows a typical spacing-frequency distribution with conventional furrow planters. The percentage of plants spaced less than 2 inches is of particular concern. The main problem with present planters is the method of placing the seed. The metering mechanisms are quite accurate, but seed bouncing in the seed tube and in the seed furrow produces nonuniformity of seed spacing. The nonuniformity of seed spacing also increases as planting speed increases. Mechanical thinning is at a disadvantage in obtaining single plants with minimum spacing variation due to the nonuniformity of the seed spacing obtained with conventional planters.

Improvement in emergence rate would also decrease the final plant spacing variation and improve results obtained from thinning. The ultimate goal is planting to stand with no thinning. Planter characteristics such as depth placement and compaction around the seed are features which can affect seedling emergence.

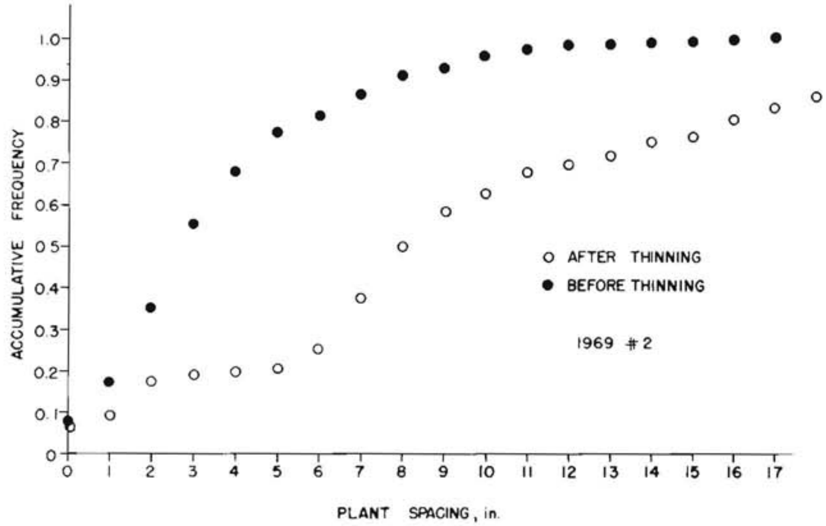


**Figure 6.—Actual plant spacing before and after selective thinning for a conventional furrow-type planter.**

Some of the present planters obtain fairly good seed spacing when operated at relatively low speeds (less than 2 mph). However, the importance of timeliness in planting seldom allows planting at this slow speed, thus increasing the seed spacing variation.

## A Precision Planter Design

***Design objectives***

The objective of this planter design was to obtain a precision sugarbeet planter which would plant with a minimum seed-spacing variation and uniform seed depth while operating at speeds greater than three miles per hour.

***Basic principles of operation***

To obtain minimum seed spacing variation, cones are mounted on the periphery of a wheel to establish conical depressions in the row for each individual seed at the desired spacing. Single seeds are metered behind the wheel into these depressions which were made in in the soil. Figure 7 shows the components of the planter.

***Depressions for seed placement***

Twelve cones are mounted on a 20-inch diameter wheel which produces approximately a 6-inch average spacing. The cones are elliptical with a 2-inch by 3-inch base and a height of 1½ inches. The major axis of the cone is placed parallel to the row.

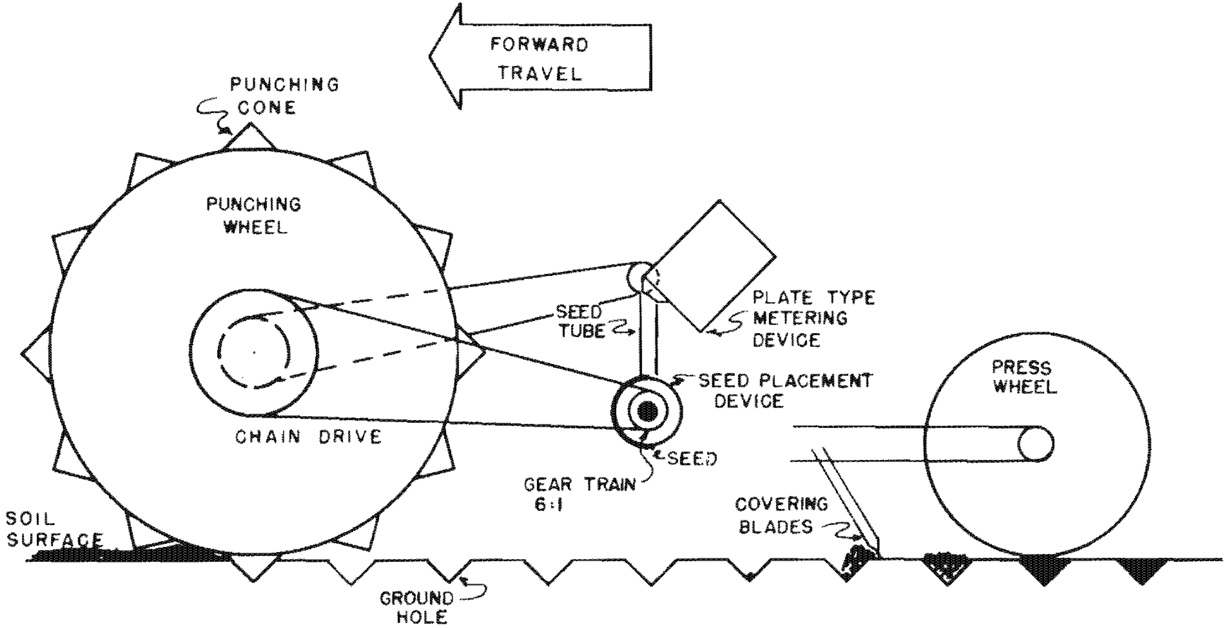


Figure 7.—Schematic diagram of space planter.

***Seed metering and placement***

A conventional cell plate metering system is used to meter the seeds into the throwing device. The particular unit used is from a John Deere[4] No. 33 vegetable planter. A round, rotating plate is used to throw the seeds backward with approximately the same speed as the forward speed of the planter. When the seed is released, it has approximately zero relative velocity with respect to the ground. The seed placement device automatically compensates for the planter's forward speed. The seed plate and placement device are chain driven by the punching wheel to maintain one seed per hole. Timing the seed-drop position to the ground hole is provided for in the gear train assembly.

*Performance of the Planter*

The space planter design seems to meet the objectives desired in a sugarbeet planter.

The seed placement device works very well at speeds up to 5 miles per hour as indicated by table 2 (7).

**Table 2.—Results of Seed-Metering Study**

| | Speed (miles per hour) | | |
|---|---|---|---|
| | 3 | 4 | 5 |
| Seeds in Holes at each speed (%) | 97.6 | 96.3 | 94.0 |
| Standard error at each speed (%) | 0.056 | 0.056 | 0.066 |

***1970 Emergence Study***

The rate of emergence obtained with the space planter was compared in the field in 1970 and 1971. The spacing uniformity was also studied.

In the 1970 studies the space planter used only the metering wheel with no cell type metering system. The emergence was compared with that obtained with a conventional type planter (an International Harvester Company[4] number 185 unit planter with Acra-plant[4] runner-type openers). Demonstration plots were all located in Wyoming near Powell, Deaver, Worland, and Riverton as well as the Powell and Torrington Substations of the University of Wyoming. Figure 8 shows the planting unit used for the demonstration plots.

Table 3 shows a comparison of emergence rates obtained at the locations where stands were established. At three locations, stands were not established with either planter, probably due to excessive crusting. At one other location, sufficient covering was not obtained with the space planter drag chain due to soil texture and high soil moisture content. At three out of four locations counted, the emergence rate for the space planter was an average 8 % better than that obtained with the conventional planter.

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[4]Company names do not represent preferential treatment or endorsement and are included for the benefit of the reader.

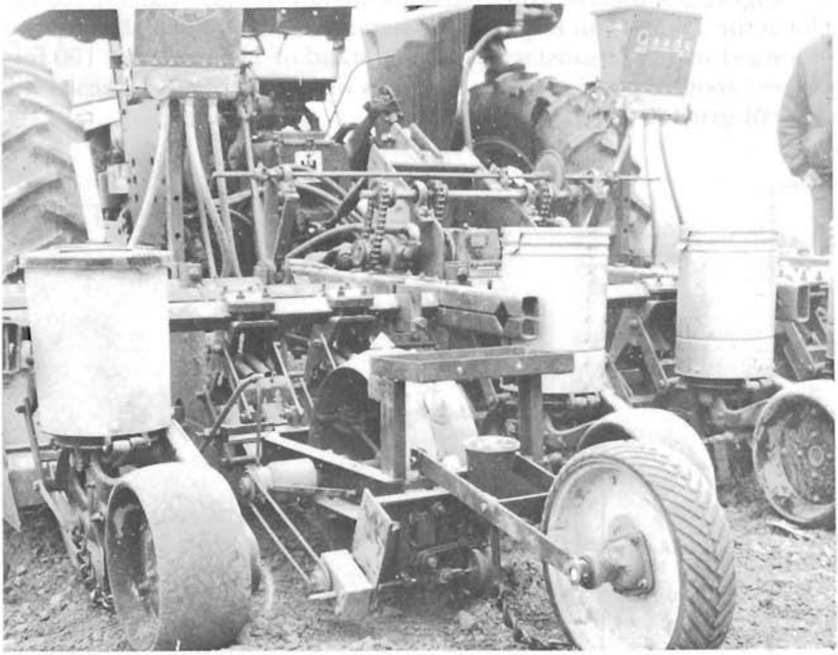

**Figure 8.—Field unit used to plant 1970 demonstration plots with space-planter mounted.**

**Table 3.—Comparison of Emergence Rates, Spring 1970**

| Location | Pre-plant herbi-cide | IH 185 Planter | | "Jafari" Planter | |
|---|---|---|---|---|---|
| | | Average* plant spacing | Emer-gence rate | Average* plant spacing | Emer-gence rate |
| Powell Exp. Sta. | Ro-Neet | 7.87 | 0.36 | 16.14 | 0.38 |
| Powell-Northrup | Pre-Beta I | 5.56 | 0.51 | 13.98 | 0.44 |
| Worland-Swing | Ro-Neet | 6.39 | 0.44 | 10.75 | 0.57 |
| Torrington Exp. Sta. | Ro-Neet | 6.07 | 0.47 | 10.17 | 0.58 |

*All spacing in inches.

Figure 9 shows the cumulative frequency of plant spacing for the plot at the Torrington Experiment Station. From a practical viewpoint this stand was quite satisfactory, with a stand of 118 beets per 100 feet of row; about 5 percent of the spacings were less than 2 inches and 2 percent greater than 26 inches.

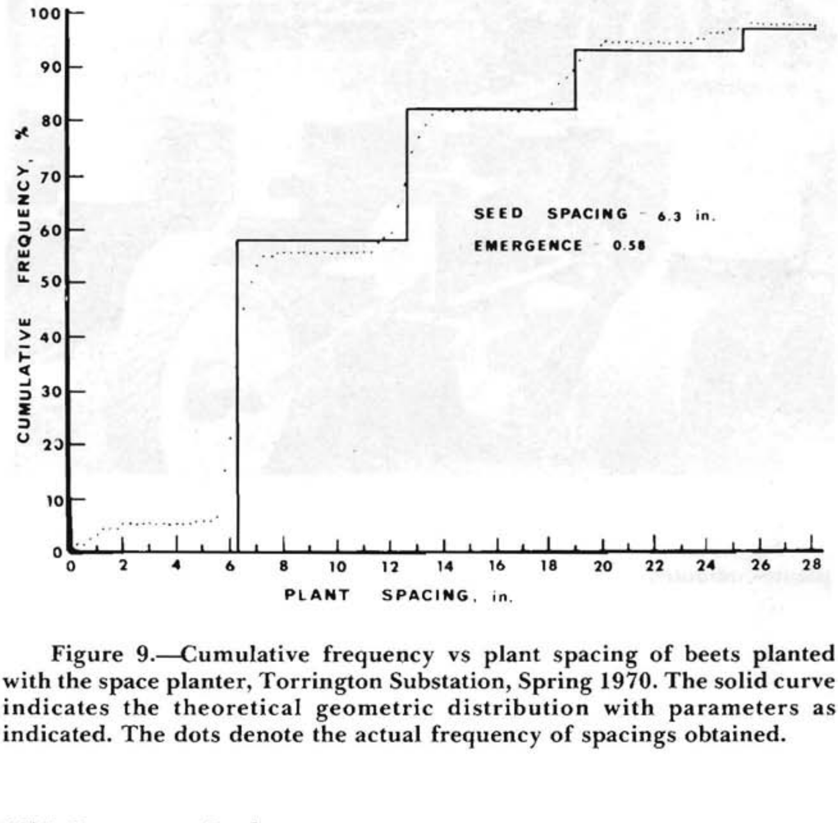


**Figure 9.—Cumulative frequency vs plant spacing of beets planted with the space planter, Torrington Substation, Spring 1970. The solid curve indicates the theoretical geometric distribution with parameters as indicated. The dots denote the actual frequency of spacings obtained.**

### *1971 Emergence Study*

The 1970 planter was not satisfactory for two reasons: (1) the seed tube feeding the metering and placement wheel clogged occasionally, thus causing skips in the row; and (2) the covering drag chain used was not sufficient for all the conditions encountered. An attempt was made to correct these problems in the 1971 planter. The cell type metering device was added with a larger seed tube, and the placement wheel groove was altered. Two adjustable blades replaced the drag chain to provide better seed covering.

All 1971 plantings were made at the Torrington Substation. A randomized slit-plot block experimental design with four replications and six different planting dates at approximately one-week intervals, were used in an attempt to utilize different soil temperatures over the emergence period. The space planter was compared with a John Deere

No.33 vegetable planter which appeared to provide much more even depth control than the unit planter used in 1970. Figure 10 shows the planter as used in the field. Wet weather conditions which included hail did not produce typical changes in Spring temperatures.

**Figure 10.—Field unit used in 1971 emergence and planting date comparisons. The left planter is a John Deere No. 33 vegetable planter, and the right planter is the Wyoming (or Jafari) space planter.**

Table 4 shows the final emergence obtained using the two-planters at the different dates. Excluding the third planting (which was exposed to hail during emergence) the two planters averaged approximately the same emergence rate. It was felt that the space-planted third planting was just emerging at the time of the hail and thus was damaged much more than the No.33 planted beets. It is difficult to come to any conclusion since emergence obtained with the space planter was significantly higher for two plantings while that obtained from the John Deere No. 33 planter was also significantly better for two plantings.

The metering system change solved the problem of clogging but did introduce some skips followed by doubles as shown by the cumulative frequency plot shown in Figure 11. The covering device worked much better than the drag chain used in 1970.

Table 4.—Comparison of emergence rates, Spring 1971, Torrington Substation.

| Date planted | Space planter | JD No. 33 planter | Difference in emergence |
|---|---|---|---|
| 4-7-71 | 0.47 | 0.40 | +0.07 |
| 4-14-71 | 0.42 | 0.28 | +0.14 |
| 4-29-71 | 0.08 | 0.41 | −0.33 |
| HAIL | | | |
| 5-14-71 | 0.61 | 0.60 | +0.01 |
| 5-21-71 | 0.58 | 0.61 | −0.03 |
| 5-28-71 | 0.57 | 0.68 | −0.11 |

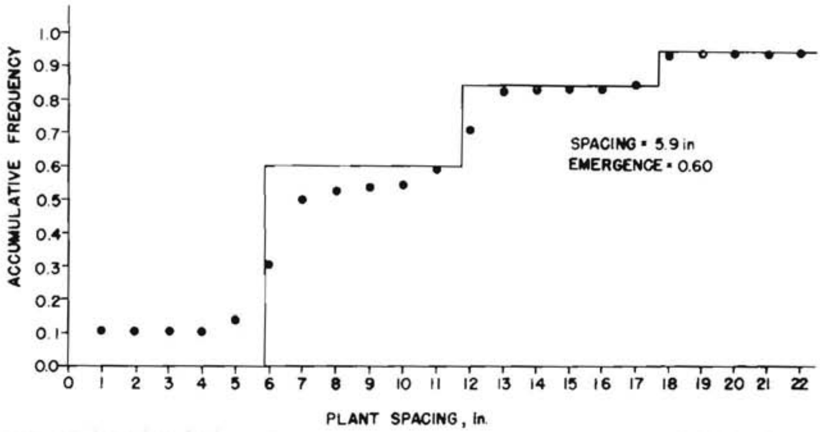


**Figure 11.—Cumulative frequency vs plant spacing of beets planted with the space planter, Torrington Substation, Spring 1971. The solid curve indicates the theoretical geometric distribution with parameters as indicated. The dots denote the actual frequency of spacings obtained.**

## Summary

Plant population greatly influences sugarbeet yield. The planting unit and mechanical thinner settings directly influence the plant stand.

Relationships for plant stand before thinning, after random thinning, and after selective thinning are presented. A plant spacing calculator was developed to find the proper thinner setting for thinning to a desired plant spacing from a known population. The length of block to be skipped is also discussed. A large block skipped, but less than the seed spacing, is desired in order to obtain the smallest standard deviation of the plant spacing.

A design of a space planter is presented. The planter employs cones on a wheel to establish a seeding depth rather than a conventional furrow opener. Results of performance tests with the planter

indicate that improved uniformities of seed placement were obtainable. Emergence rates are about equal to those found for some conventional-type planters.

## Acknowledgment

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