Development of a Synchronous Thinner

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For crops such as sugar beets, cotton, tomatoes and lettuce, planting to stand is hampered by problems in planting the seeds accurately and by hazards such as low germination rates, soil crusting and bird and insect damage. Over planting is necessary to increase the probability of obtaining an adequate stand, and subsequently the crops must be thinned.

Hand thinning is difficult and tedious; the supply of labor to do the work is uncertain; and the cost is high.

Random mechanical blocking has been practiced for many years, and a wide variety of machines is available. With uniform emergence, they produce acceptable stands for many crops. But in poorly distributed stands or where single isolated plants must be left at fairly long intervals, the change of leaving blocks devoid of plants is high.

Synchronous thinning is a controlled blocking operation in which blocking is synchronized with plants in the row. The thinner senses the location of a plant and actuates a cutter which removes adjacent plants. Then the machine moves down the row until it senses another plant. The spacing between plants varies, but there are no blocks without plants. The number of excessively long gaps, which amount to reduced acreage, is significantly less than with random mechanical blocking.

The upper part of Figure 1 shows schematically a crop planted with seeds at two-inch intervals. Plants emerged in 60% of the hills. The center part of the figure shows two-inch-wide blocks left at 12-inch intervals by a random blocker. One of the blocks is void leaving 24 inches between adjacent plants. By comparison, the lower portion of the figure shows the pattern of a thinner which cuts out portions of the row only after it senses the presence of a plant. The length of the block is varied to insure inclusion of a plant, and the cutting action is synchronized on that plant. In Figure 1 the longest distance between adjacent plants thinned by this synchronous thinner is 14 inches.

Average Plant Spacing Resulting from Thinning

The random blocker removes portions of the plant row at regular intervals. In order to leave isolated plants, the size of

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the block must be reduced to contain only one hill, and each hill must contain only one plant. Under these conditions, the average spacing of plants after thinning is

$$\bar{X}_r = \frac{ma}{p}$$

where

m = spacing of blocks, hills/block
a = spacing of hills, inches/hill
p = proportionate stand prior to thinning

A synchronous thinner leaves a minimum block spacing of (ma), but unless a plant is detected immediately the block spacing increases until a plant is detected. The average plant spacing after synchronous thinning can be expressed (4)[2] as

$$\bar{X}_s = ma + a\frac{(1-p)}{p}$$

It will be noted that the average plant spacing is a constant amount larger than the minimum for a particular hill spacing and proportionate stand. Figure 2 shows the manner in which $(\bar{X}_s)$ depends upon the various parameters. For the thinning of some crops it may be desirable to estimate the proportionate stand and use a length of cut which will produce the desired average plant spacing. Figure 2 should be helpful in determining the proper length of cut. For other crops the minimum plant spacing is more important than the average.

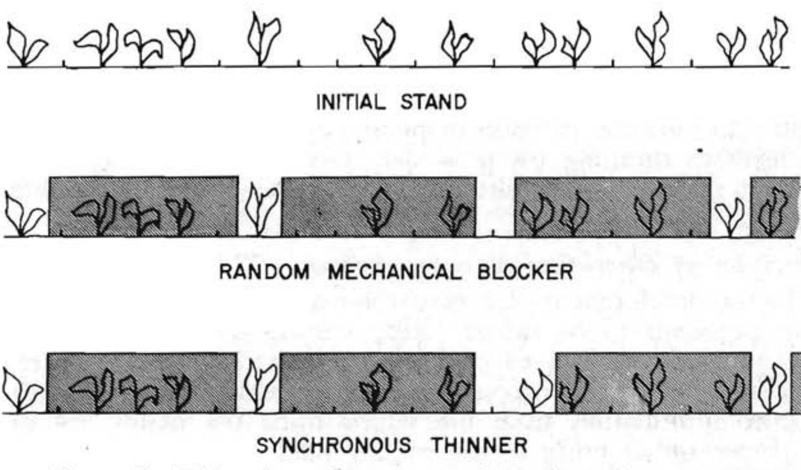

Figure 1.—This schematic representation of a plant row compares the action of a random blocker with that of a synchronous thinner.

[2] Numbers in parentheses refer to literature cited.

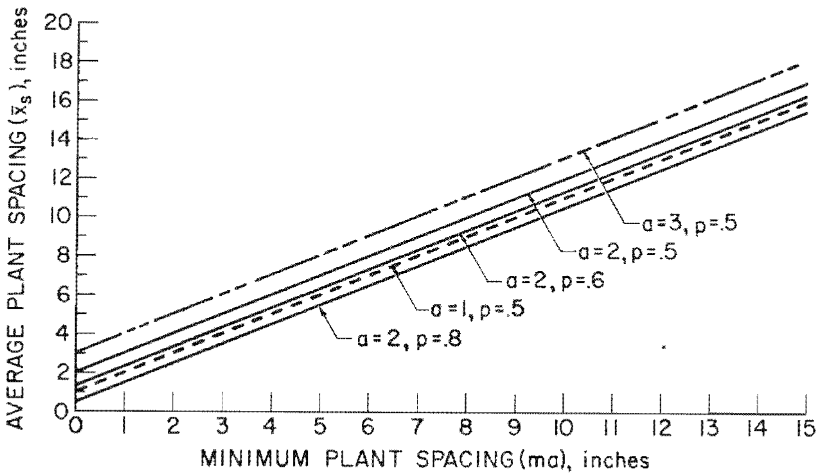

Figure 2.—Plant spacing relationships after synchronous thinning.

For a given minimum plant spacing, synchronous thinning will result in a stand with more plants per acre than will random blocking. The increase in plant population can be expressed as

$$I = \frac{\bar{X}_r - \bar{X}_s}{\bar{X}_s}$$

As the minimum plant spacing increases, the increase in plant population approaches the limit

$$\lim_{ma \to \infty} I = \frac{1 - p}{p}$$

Figure 3 shows the increase in plant population resulting from synchronous thinning for p = .60. The scale on the right of Figure 3 shows the limit of the increase for several proportionate stands.

Principles of Operation of a Synchronous Thinner

In the development of a synchronous thinner, there are two main problems to be solved: first, sensing the presence of a plant which is to be saved, and second, operating a cutter intermittently. It may be necessary also to provide a memory unit to store information from the sensor until the plants are in the correct relationship to the cutting blade.

Several approaches to synchronous thinning have been reported (1-8). Sensing methods incorporating mechanically actuated switches, interrupted light beams and reflected light have

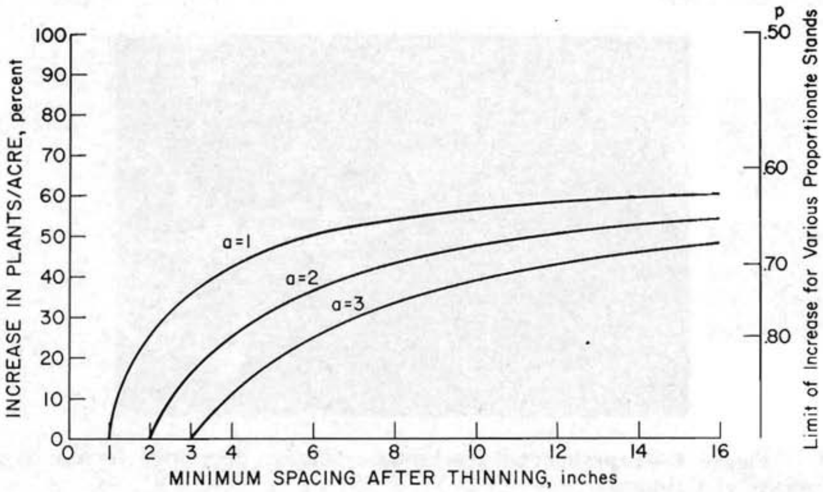

Figure 3.—Theoretical increase in resultant plant population. Synchronous thinning compared to random thinning —.60 Proportionate stand.

been used. While some of the proposals have involved delicate and expensive apparatus, they have been generally successful in principle.

The synchronous thinning machine developed by the University of California senses plant location by completing an electrical circuit through the plant. A length of copper tubing mounted on an insulating block serves as the plant probe. It is suspended slightly above the ground so as to contact plants in the row. A second probe operating in the soil completes the circuit when the copper tubing contacts a plant.

A cutting blade, powered by an electrically controlled pneumatic cylinder, is suspended from a shaft above and parallel with the plant row. The blade is ahead of the plant probe. When a plant contacts the probe, an electronic circuit causes the pneumatic cylinder to stroke, moving the cutting blade through the row just forward of that plant. The blade removes all plants for a distance determined by the length of the blade. The pneumatic cylinder holds its position until a second plant is contacted; then the cylinder makes a return stroke. As the machine moves down the row, it continues this alternate cutting operation with each stroke synchronized to a plant which is left in a block.

Figure 4 shows the experimental thinner. A gage wheel running on the center of a double-row bed controls the height

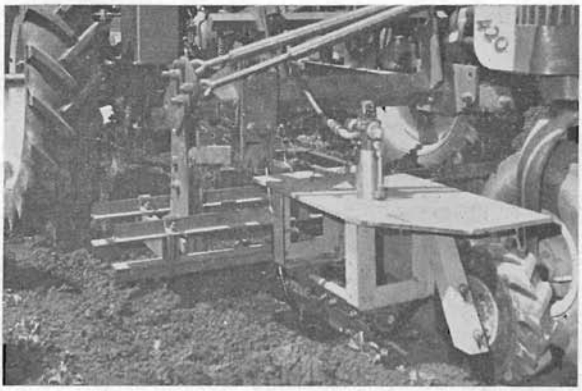

Figure 4.—Experimental synchronous thinner developed by the University of California.

of the probe and the depth of cut. In this view the thinner is mounted on a conventional cultivator tool bar.

Cultural Requirements

The ability of the synchronous thinner to isolate single plants depends to a large extent on the spacing between plants prior to thinning. Due to variations in plant size and shape, there is a limitation to the accuracy with which the thinner can locate a plant stem. In one case the probe may contact a plant leaf two and one-half inches ahead of the stem, and in another case, it may not contact a plant until it is only one-half inch from the stem. In order to prevent cutting the plant which was contacted in the first case, the blade must not cut for at least two and one-half inches ahead of the contact point, but if it does not cut until that far ahead of the point at which it contacts the plant in the second case, it will leave anything that is within two inches of that plant. If the thinner is to leave single plants, the plants in the initial stand must be spaced an amount greater than the variation in the distances from the points of contact to the plant stems. As the spacing between plants increases, it becomes easier to leave single plants, but the average spacing after thinning also increases. The choice of the proper plant spacing is influenced by the importance of leaving single plants, the importance of average and minimum plant spacing after thinning, the probable size of the plants at thinning time and the characteristic shape of the plants. Further research is necessary to determine the optimum spacing, but at present it seems desirable to have plants spaced about two inches apart.

The plant detection system used on the synchronous thinner developed by the University of California does not discriminate between plant species. Furthermore, it can be triggered if the probe contacts moist soil. Thus, for its successful operation, good weed control and smooth seed beds are essential.

Weed control is important for two reasons. First, even if the initial spacing of crop plants is adequate, weeds in proximity to a plant that is contacted will be left also. Second, a weed may be contacted instead of a crop plant, and the blocking action will be synchronized on the weed. By good mechanical design and careful operation, the thinner can be made sensitive only to weeds which invade the plant row. If all crop plants are fairly tall, the probe can be positioned above close-growing weeds.

Normally the probe is operated as close to the soil surface as possible. This enables it to contact small plants and to establish better contact with larger plants. But the probe must not contact the soil surface or a false signal will be given. The plant row must be smooth and free from clods, and the height relationship between the plant row and the surface from which height is gaged must be consistent. This requires good bed shaping and a minimum of disturbance prior to thinning. With hand thinning, it is customary to cultivate prior to thinning. This practices reduces the effort required to chop out a portion of the row. But cultivation tends to disturb the gaging surface and introduce clods into the plant row. Thus, synchronous thinning should be done ahead of cultivation.

Operating Characteristics

Even with good soil preparation, adequate weed control and spaced planting, a careful operator is required if the thinner is to function properly. The first and most obvious requirement for operating is to keep the thinner guided on the row. The probe must be kept in line with the plants, and the axis of rotation of the blade must be kept over the row in order to insure proper depth of cut.

In addition to guiding the thinner accurately, the operator must control the forward speed of the machine. The distance from the point of plant contact to the portion of the row that is cut out is a function of several design parameters, but, because of inherent time lags in the system, it is also a function of the forward speed. Once the machine has been adjusted for a particular crop with reference to initial spacing, final spacing, plant size and desired speed of travel, it is necessary for the operator to control the speed of travel to achieve satisfactory results. If he drives too slowly, he may either cut out the plant he wants to leave or trigger the cutter twice on the same plant. If he drives too fast he may leave multiple plants, or he may reach the next plant beyond his cut before the electronic circuit is ready to act on it and again leave multiple plants.

Depth of cut and height of the probe both require careful adjustment in accordance with field conditions. The cutter should shear unwanted plants below their crowns in order to be sure of killing them. In loose, cloddy soil this may be difficult. Rolling clods tend to push the plants over before the cutter reaches them.

Many plants tend to become woody and tough as they get older. In spite of the high velocity of the cutter blade, some plants will bend rather than cut. Plants need to be thinned when they are large enough to be sensed but young enough to be cut and small enough to minimize errors in locating the plant stems. The ability of the operator to judge the correct time for thinning will effect the success of the thinner.

Conclusions

The principles of operation incorporated in the synchronous thinner developed by the University of California lend themselves to simple and rugged construction. No memory unit or ground distance measuring device is required. The probe is positioned behind the cutting blade, and the cutting blade physically removes all unwanted plants for the desired distance down the row. A simple change in the length of the cutting blade will change the minimum plant spacing after thinning making the machine adaptable to a wide variety of conditions.

The experimental unit has been used successfully with sugar beets, cotton, tomatoes, lettuce, broccoli and melons. It has not been tested with other crops. With good management and careful operation, synchronous thinning can isolate single plants at any desired minimum spacing with significant reductions in the number of long gaps which amount to lost acreage.

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