Effect of In-the-Row Spacing of Single, Double, and Multiple Plant Hills on Beet Sugar Production

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In considering the use of down-the-row mechanical thinners, it is important to know the degree that sugar beets will tolerate close spacing in the row. The more plants that can be tolerated without reducing yields, the easier mechanical thinning becomes and the less the chance of creating gaps unoccupied by plants. To learn more as to the effects of high in-the-row populations, three experiments were conducted at Davis, California.

Earlier experiments have shown little or no reduction in beet yield with in-the-row spacings as close as eight inches (4)[2] (5) (7). Deming concluded that up to 25 hills per 100 feet of row containing 2 or 3 plants could be left on 12-inch centers without reducing root yield (2). Later he found that a population containing 25 percent double and 5 percent three-plant hills on 12-inch centers reduced root yield slightly in comparison with a stand containing 100 percent single beet hills (3).

With the increased use of mechanical thinners, it was felt that more information should be obtained as to the effects of close in-the-row spacing of single, double, and multiple plant hills in order to use these machines most effectively.

Procedure

Three field experiments were conducted in successive years. Sugar beets were planted on beds spaced 40 inches from center to center. The spacing between rows was 14 x 26 inches. In the trials in 1952 and 1953, the variety US 22/3 was planted; and in 1954, US 75 was used. Seedlings were thinned by hand to leave the desired population of single, double, or multiple (three or more beets) hills. The single, double, and multiple hills were placed in a regular arrangement along the row at approximately equal distances from each other.

In 1952 and 1954, a randomized block design was used. In 1953, a split plot design was employed with nitrogen levels as main plots and populations as sub plots.

Individual plots were two beds (four rows) 60 feet long or, when different fertility levels were employed, four beds 60 feet long.

When fertility was not a variable, nitrogen was applied to all plots at the rate of 160 pounds per acre, half applied at thinning and half at mid season. Ammonium nitrate was the nitrogen source used in all experiments. In 1953, when fertility was a variable, plots receiving nitrogen received 80 pounds per acre at thinning and the balance of the total rate at mid-season. See Table 2 for nitrogen rates. All fertilizer applications were applied as side dressings.

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[2] Numbers in parentheses refer to literature cited.

Harvest data were taken from 50 feet of four rows per plot. Four samples were taken from each plot for sucrose and tare determinations. Beets less than two inches in diameter were discarded before weighing in the 1953 and 1954 experiments. In 1952, beets with a diameter exceeding approximately one inch were considered marketable.

Results and Discussion

Experiment 1, 1952

In-the-row spacings of single and double plant hills and harvest results are indicated in Table 1. Thinned populations as high as 300 plants per 100 feet of row had no appreciable effect on root yield, sucrose percent or sugar produced. This was true whether the 300 beets were thinned to singles four inches apart or spaced six inches apart with 50 percent of the hills containing two beets. Stand counts at harvest showed the number of beets in the high population plots had diminished greatly. In the higher populations, a greater percentage of plants either died or did not develop into marketable beets.

Experiment 2, 1953

This experiment was designed to study the influence of different levels of double and multiple hills on sugar production at varying levels of soil fertility. The original plan was to establish populations containing different percentages of doubles and multiples in hills spaced eight inches apart. The seedling stand, however, was not full enough to accomplish this, so hills were spaced 12 inches apart. Table 2 indicates the populations, nitrogen levels, and their effects on root yield, percent sucrose, and gross sugar.

There was a marked response to nitrogen with all populations reacting similarly to the different nitrogen levels. The three populations produced equally good root yields, sucrose percentages, and gross amounts of sugar.

Table 3 brings out an interesting effect of fertility on the ability of these populations to develop marketable beets. There was a significant interaction of nitrogen and populations in regard to numbers of marketable

Table 1.—Effect of Hill Spacing and Doubles on Root Yield, Percent Sugar, Gross Sugar, and Marketable Beets. Experiment 1, 1952.

Thinned Stand		Marketable Beets at Harvest[1]				
Spacing in Row (Inches)	Total Beets Per 100 Feet	Total per 100 Feet	Percent of Thinned Stand	Tons Per Acre	Percent Sucrose	Tons Sugar Per Acre
12	100	102	102	22.9	16.5	3.77
12 (½ doubles)	150	139	93	23.0	16.7	3.83
8	150	145	97	23.4	16.6	3.89
6	200	175	88	23.9	16.4	3.93
6 (½ doubles)	300	176	59	23.0	16.5	3.79
4	300	184	61	23.9	16.8	4.01
Significant differences, 5% level:				ns[2]	ns	ns

[1] Beets larger than 1 inch in diameter

[2] Not significant

Table 2.—Effect of Nitrogen and Stand on Root Yield, Percent Sucrose, and Gross Sugar. Experiment 2, 1953.

Thinned Stand (12 inch centers)								
Beet Hills Per 100 Feet			Total Beets Per 100 Feet	Pounds of Nitrogen Per Acre				Average Effect of Multiples and Doubles
Singles	Doubles	Multiples		0	80	160	240	
				Tons Beets Per Acre				
100	0	0	100	22.3	27.1	30.3	33.4	28.3
62.5	25	12.5	150+[1]	24.5	28.1	31.1	32.4	29.0
25	50	25	200+	22.6	27.5	31.0	31.2	28.1
Average effect of nitrogen				23.1	27.6	30.8	32.3	
Significant differences, 5% level: Interaction—ns; average effect of nitrogen—1.9; average effect of multiples and doubles—ns								
				Percent Sucrose				
100	0	0	100	15.3	15.3	14.7	13.9	14.8
62.5	25	12.5	150+	15.6	15.4	14.8	14.1	15.0
25	50	25	200+	15.4	15.2	14.8	14.0	14.8
Average effect of nitrogen				15.4	15.3	14.8	14.0	
Significant differences, 5% level: Interaction—ns; average effect of nitrogent—0.5; average effect of multiples and doubles—ns								
				Tons Gross Sugar Per Acre				
100	0	0	100	3.40	4.15	4.42	4.63	4.15
62.5	25	12.5	150+	3.80	4.31	4.60	4.57	4.32
25	50	25	200+	3.47	4.19	4.60	4.35	4.15
Average effect of nitrogen				3.56	4.21	4.54	4.51	
Significant differences, 5% level: Interaction—ns; average effect of nitrogen—0.28; average effect of multiples and doubles—ns								

[1] Minimum number. Multiple hills have been calculated at 3 plants per hill, but often contained more.

Table 3.—Effect of Nitrogen and Stand on Marketable Beets. Experiment 2, 1953.

Thinned Stand (12" Centers)								
Beet Hills Per 100 Feet			Total Beets per 100 Feet	Pounds of Nitrogen Per Acre				Average Effect of Multiples and Doubles
Singles	Doubles	Multiples		0	80	160	240	
				Number of Marketable[1] Beets Per 100 Feet				
100	0	0	100	96	100	99	100	99
62.5	25	12.5	150+	127	138	135	137	134
25	50	25	200+	143	164	163	160	158
Average Nitrogen effect				122	134	133	132	

Significant differences, 5% level: Interaction—between nitrogen means for the same stand—7; average nitrogen effect—5; average effect of multiples and doubles—3.

[1] Beets larger than 2 inches in diameter

beets at harvest. When beets were thinned to a single plant every 12 inches, increasing soil fertility had no effect on the number of marketable beets. There was essentially no change in plant population from thinning to harvest. But when doubles and multiples were left, increasing soil fertility had a definite effect on marketable beets. More marketable beets developed under crowded conditions when the plants received nitrogen than when nitrogen was not added. The fact that this differential effect was not reflected in root yields is readily explained. It is well established that beet root yields are not appreciably improved by spacing plants closer than 12 inches in the row (1). Since none of the stands in this experiment consisted of plants spaced more than 12 inches apart, higher populations would not be expected to increase yields.

Experiment 3, 1954

This experiment contained the same population as in 1953, but, to further test the effects of high populations, stands containing the same percentages of doubles and multiples were also established at eight- and four-inch centers. Table 4 shows the number of hills and total beets per 100 feet of row left at thinning.

In this trial, Table 5, there were highly significant interactions between percentages of doubles and multiples and hill spacing with respect to root yield and gross sugar. High percentages of double and multiple hills on 12 inch centers did not reduce yields. On eight inch centers, the highest population, 25 percent multiple and 50 percent double plant hills, reduced root yield by 1.3 tons per acre. On four inch centers both levels of doubles and multiples reduced yields nearly four tons per acre. This is perhaps the most important effect observed in the experiment and is the basis for considering precision planting of sugar beets in hills (6).

Table 4.—Percentage of Singles, Doubles, and Multiples, Hills Per 100 Feet and Total Plants Per 100 Feet, Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hills Per 100 Feet[1]			Total Plants Per 100 Feet
Singles	Doubles	Multiples	Singles	Doubles	Multiples	
			12-inch Centers			
100	0	0	100	0	0	100
62.5	25	12.5	62	25	13	150[2]
25	50	25	25	50	25	200[2]
			8-Inch Centers			
100	0	0	150	0	0	150
62.5	25	12.5	94	37	19	225[2]
25	50	25	37	75	37	300[2]
			4-Inch Centers			
100	0	0	300	0	0	300
62.5	25	12.5	187	75	37	450[2]
25	50	25	75	150	75	600[2]

[1] Decimal values have been rounded off to whole hills.
[2] See footnote 1 Table 2.

Table 5.—Effect of Hill Spacing, Doubles and Multiples on Root Yield, Percent Sugar and Gross Sugar. Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hill Spacing (Inches, Center to Center)			Average Effect of Multiples and Doubles
Singles	Doubles	Multiples	12	8	4	
			Tons Beets Per Acre			
100	0	0	22.7	22.2	21.2	22.0
62.5	25	12.5	21.8	21.3	17.3	20.2
25	50	25	22.2	20.9	17.4	20.2
Average spacing effect			22.2	21.4	18.7	
Significant differences, 5% level: Interaction—1.4; average effect of multiples and doubles—0.8; average effect of spacing—0.8						
			Percent Sucrose			
100	0	0	16.7	17.0	17.0	16.9
62.5	25	12.5	16.4	16.9	17.2	16.9
25	50	25	16.8	16.7	17.3	16.9
Average spacing effect			16.6	16.9	17.2	
Significant differences, 5% level: Interaction—ns; average effect of spacing—0.3; average effect of multiples and doubles—ns.						
			Tons Gross Sugar Per Acre			
100	0	0	3.79	3.76	3.62	3.72
62.5	25	12.5	3.58	3.61	2.98	3.39
25	50	25	3.73	3.48	3.01	3.41
Average spacing effect			3.70	3.62	3.21	
Significant differences, 5% level: Interaction—0.27; average effect of multiples and doubles—0.16; average effect of spacing—0.16.						

Single plants spaced four inches apart reduced root yield by 1.5 tons per acre compared to those spaced 12 inches. This was not observed in 1952. A possible explanation of the conflicting results might be the fact that in 1952 all beets greater than one inch in diameter were weighed while only those greater than two inches were included for yield determinations in 1954. Unfortunately, these unmarketable beets were not counted or weighed in either of these trials. Other data have been obtained, however, indicating that from one to two tons of roots per acre are lost through discarding beets two inches or less in diameter (6).

There was an average increase of a 0.6 sucrose percentage point with the closer hill spacings. Although the interaction of hill spacing with multiples is not significant at the 5 percent level, the increase is greater as hill spacing is decreased with stands containing doubles and multiples than when single plant stands are compared at different hill spacings.

Table 6 indicates that, as in the 1952 experiment, many plants do not develop into marketable beets when stands are thick. It is felt that many beets were discarded as "unmarketable" in the 1953 and 1954 experiments which actually would have been recovered by commercial harvest. Consequently these results may be somewhat biased in favor of lower populations.

Table 6.—Effect of Hill Spacing, Doubles and Multiples on Marketable Beets. Experiment 3, 1954.

Thinned Stand Percent Hills Containing:			Hill Spacing (Inches, Center to Center)		
Singles	Doubles	Multiples	12	8	4
			Total Plants Per 100 Feet at Thinning		
100	0	0	100	150	300
62.5	25	12.5	150+[1]	225+	450+
25	50	25	200+	300+	600+
			Marketable Beets at Harvest[2]		
100	0	0	82	.111	181
62.5	25	12.5	106	151	187
25	50	25	141	171	191
			Marketable Beets as Percent of Plants at Thinning		
100	0	0	82	74	60
62.5	25	12.5	71—[1]	67—	42—
25	50	25	71—	57—	32—

[1] Minimum number, multiple hills calculated at 3 plants per hill but often contained more. Hence the + and — markings.

[2] Beets larger than 2 inches in diameter.

Summary and Conclusions

Three population experiments were conducted in which an attempt was made to assess the effects of various percentages of double and multiple (three or more beets) beet hills in the stand upon sugar beet production. From these studies the following ideas evolved:

1. Sugar beets spaced evenly showed little yield variation over a range of 4 to 12 inches between singly spaced beets.

2. Fifty percent doubles introduced into stands of beets evenly spaced at 6 or 12 inches did not cause yield reductions.

3. When hills were spaced rather evenly at 12-inch centers, there were no differences in root and sugar yields among populations containing 100 percent single plants, 25 percent doubles and 12.5 percent multiples, or 50 percent doubles and 25 percent multiples.

4. At an 8-inch hill spacing the yield was reduced 1.3 tons per acre when 50 percent doubles and 25 percent multiples were included in the stand.

5. At a spacing of four inches between beet hills, the introduction of doubles and multiples resulted in a yield reduction of 3.8 tons per acre.

From a practical standpoint it appears from these studies that as long as hills are spaced 10 to 12 inches apart, large percentages of doubles and multiples can be tolerated. This suggests that hill planters designed to drop several seed units close together at 12-inch centers or the use of down-the-row thinners with larger knives on the original pass through the field may be successful in reducing or eliminating thinning costs without lowering yield.

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