Effect of Uniformity of Within-Row Plant Spacing on Sugarbeet Yield

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Research studies have shown that plant population, for a given row spacing, will influence sugarbeet root yield and sugar content of the roots (e.g., Yonts and Smith, 1997). However, the influence of the spacing pattern of the plants within the row, for a given plant population, on sugarbeet yield is less clear. To achieve maximum yield, must the plants be spaced equidistant within the row, without large gaps or small spacings between plants? Will a few gaps or some minor spacing inaccuracy within the row influence yield?

Perhaps the best answer appearing in the literature is a study conducted by researchers in North Dakota and Minnesota (Smith, Cattanach, and Lamb, 1989). Three patterns of irregularly spaced plants were compared to uniformly spaced plants, all in five plant populations. The general conclusion of the investigators was that, within a given plant population, uniformly spaced plants did not provide a yield advantage over the irregular plant spacing patterns used in that study. However, at the plant population which provided highest recoverable sugar, the spacing treatment with uniformly spaced plants did have a higher root yield than at least one of the patterns with irregularly spaced plants. Root yields averaged over sites and years ranged from 15.5 to 17.3 ton/A for the combinations of plant spacing patterns and plant populations.

In growing areas where field yields of 20 - 30 ton/A are possible, will plant spacing accuracy within the row influence yield if other yield limiting factors (disease and insect pests, soil moisture, nutrients) are minimized?

Objective

The objective of this study was to determine if accurate and uniform spacing of plants within the row will provide a sugarbeet yield advantage compared to irregularly spaced plants within the row, at the same plant population.

Procedure

The study was conducted at the University of Nebraska Panhandle Research and Extension Center near Scottsbluff, NE. The soil in the plot area is generally described as a very fine sandy loam with a typical pH of 8.0 and O.M. of 0.8%.

This study included four "sites", site 1 in 1996, sites 2 and 3 in 1997, and site 4 in 1998. Site 1 included a total of ten patterns of in-row spacing, described in Table 1 and Figure 1 as spacing patterns 1-10. Patterns 1-5 were intended to simulate a high emergence field situation with a resulting high target plant population of 36,000 plants/A. Patterns 6-10 were designed to simulate a lower emergence field situation with resulting larger plant spacings within the row and a lower target final plant population of 20,000 plants/A. Patterns 1 and 6 had very accurate and uniform plant spacing within the row, while the other eight patterns had different arrangements of close plant spacings and relatively small gaps. Patterns 1-5 were intended to be similar to patterns 6-10, respectively, except for plant population.

Yield results from the 1996 study indicated no statistically significant yield differences among the 10 spacing patterns, so two, more exaggerated spacing patterns of longer gaps and sections of closer plant spacings, were added for sites 2-4. Pattern 11 was designed with a plant population of 36,000 plants/A and the similar pattern 12 had a target plant population of 20,000 plants/A.

Plots were arranged in a randomized complete block design with six replications per site. Plot size was four-22 in. rows wide by 25 ft long. Plant patterns were established by planting to stand, with no plant thinning. The plots were planted with a Deere model 71 Flexi-planter with custom made seed plates. Standard 72 cell plastic plates were modified by filling the appropriate holes to provide the correct spacing pattern. The planter transmission was adjusted to give the correct plant population. Plots were planted at ½ mph to maximize seed spacing accuracy.

The previous crop in the plot area for each site was dry edible beans. The plot area was fertilized for a 30 ton/A crop yield, based on soil tests. The soil was fumigated with Telone II at 12 gal/A for nematode control, moldboard plowed, and roller harrowed once. The final seedbed was prepared with a European made seedbed preparation implement. The variety Seedex Monohikari in regular pellet form, was used for all four sites. Sprinkler irrigation was used as needed to achieve a high emergence. Weeds were controlled with a combination of herbicides (chosen to minimize influence on emergence and plant stand), cultivation, and hand weeding. Insecticides and fungicides were used as needed to minimize crop injury from insect and disease pests. Season long sprinkler irrigation was scheduled for maximum yield.

Plots were harvested with a share-type lifter and hand topped in site 1. Sites 2-4 were machine defoliated and machine dug. The root weight of the middle two rows of each plot was measured and root samples were taken to the Western Sugar Gering Tare Laboratory for determination of root tare and percent sugar.

Results and Discussion

The locations of all plants within each of the four rows of all plots were measured for each of the four sites. Plant spacing histograms for all 12 spacing patterns in site 4 are shown in Figures 2 and 3. These spacing distributions are typical for all four sites. Seedling emergence averaged greater than 85% for all four sites.

Two parameters were calculated from the plant spacing measurements to quantify aspects of the actual plant spacing patterns in the plots. One parameter is termed "mode spacing ±½ in".

This parameter is based on the actual mode (most frequent) spacing measurement, which should be near the actual planter seed spacing, or it is based on an assigned pattern spacing. The mode values used for this parameter are given in Table 1 for each pattern. The mode spacing ±½ in. value is the percentage of the total plant spacings which are within plus or minus ½ in. of the mode spacing value listed in Table 1. For example, a mode spacing ±½ in. value of 35% for pattern 2, would mean that 35% of all the measured plant spacings in pattern 2 were between 5 and 6 in. This parameter is often used in Europe as a practical, layman, term to describe plant spacing accuracy of planters (L'Institut Technique Francais de la Betterave Industrielle, 1994).

The second plant spacing parameter used to quantify spacing patterns is the percentage of plant spacings greater than 16.5 in. The value 16.5 in. was chosen because it is a multiple of 5.5 in., the basis of most of the patterns, and because it is popularly thought that spacings greater than approximately this value will begin to cause yield loss and an increase in late season weed escapes.

Because site 1 did not include patterns 11 and 12, the yield data from this study was analyzed in two sets. Table 2 contains the data set for patterns 1-10, averaged over all four sites. Root yields ranged from 27.8 ton/A to 35.6 ton/A within sites 1-4 when averaged over patterns 1-10. These root yields suggest the crop achieved near potential yield for the Scottsbluff area. Percent sugar was lower than the regional long term average, although typical for the years 1996-1998.

The patterns with high plant population had higher root tare, higher percent sugar, and higher sugar yield per acre than the patterns with lower plant population, when averaged over all four sites (Table 2). There was no difference in root yield. There were no differences in root yield, percent sugar, or sugar yield among patterns 1-10 when averaged over all four sites.

The second set of data was analyzed with patterns 1-12 averaged over sites 2-4 (Table 3). With this analysis the combined patterns with higher plant population produced higher root tare, higher root yield, and higher sugar yield than the combined patterns with lower plant population, when combined over the three sites. There was no difference in percent sugar. Pattern 12 had lower root yield than all other low (and high) population patterns. Pattern 11, with most radical spacing pattern among the high population patterns, had lower root yield than three of the other high plant population patterns. There were no differences in percent sugar among the individual patterns. Differences in sugar yield among the patterns was a refection of root yield differences.

The spacing parameters mode spacing ±½ in. and large spacings >16.5 in. provide some insight into the extent of plant spacing inaccuracy for each pattern but do not convey the complete spacing picture. For example, Table 3 indicates that 48.5% of the spacings in pattern 1, averaged over four sites, were within 6 ½ and 7 ½ in., and only 3.2% of the spacings were over 16.5 in. These two parameters correctly describe a very accurately spaced pattern, as verified by the histogram of pattern 1 in Figure 2. However, pattern 11 is not completely described by 15.5% of spacings within 5 and 6 in. and 9.7% of spacings over 16.5 in. The histogram of pattern 11 in Figure 2 shows that the major characteristic of pattern 11 is a combination of very long gaps and very narrow spacings.

Summary and Conclusions

This study compared sugarbeet yield of twelve in-row plant spacing patterns, six at a target plant population of 20,000 plants/A and six at 36,000 plants/A, in four sites. The two spacing patterns, one in each plant population, that included large gaps and accompanying close spacings, did have statistically lower root yields than all or most other spacing patterns within the respective plant populations. These two spacing patterns (patterns 11 and 12) would be considered extreme and would only occur in the field with very low emergence or very erratic planter performance. The sugarbeet yields of the five 'less extreme' spacing patterns, including an accurately spaced pattern, in each population, were not statistically different.

Although an extreme spacing pattern was required to show a statistically significant yield impact compared to accurate plant spacing, it is logical that some level of 'spacing inaccuracy' between 'precise' and 'extreme' caused some yield decrease hidden by ordinary experimental variation within this study. A yield loss of ½ ton/A is an important grower issue whereas the lsd value to determine differences among root yields of the spacing patterns of Table 3 is approximately 1 ½ ton/A. The point is we should not assume that only extreme spacing inaccuracy will cause yield decrease.

A practical perspective of these results is that growers should use available planter and plant establishment technology to obtain high seed spacing accuracy and high field emergence. In addition to minimizing the possibility of yield loss, uniform plant spacing and minimal large gaps will result in more uniform sized roots, fewer late season weed escapes, more uniform root scalping, and less harvest loss. High plant population and narrow row spacing will help minimize the effects of any gaps between plants.

References

Yonts, C.D. and J.A. Smith. 1997. Effects of plant population and row width on yield of sugarbeet. Journal of Sugarbeet Research 34(1-2):21-30.

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Table 1. Description of in-row spacing patterns.

Spacing Pattern No.	Simulated Field Emergence (%)	Target Final Plant Population (plants/A)	Spacing Pattern Descriptions	Assigned Plant Spacing Mode[1] (in.)
1	90	36,000	Very accurate seed spacing. One plant out of 10 potential positions is missing.	7
2	70	36,000	Single, very accurate seed spacing. One plant in each of 4 potential positions is missing.	5 ½
3	70	36,000	Within 10 potential seed positions, 3 consecutive plants are missing and one single is missing.	5 ½
4	70	36,000	Of four potential seed positions, one plant is missing and 3 are 'slightly' out of position.	5 ½
5	70	36,000	Similar to pattern #4 except more inaccurately spaced.	5 ½
6	50	20,000	Plants are very accurately spaced.	14
7	40	20,000	Plants are accurately spaced in pattern of potential positions: one missing, one present, two missing, one present, repeat.	5 ½
8	40	20,000	Plants are accurately spaced in pattern of potential positions: 3 plants missing, 3 plants in position, repeat.	5 ½
9	40	20,000	Three plants missing then 3 plants in position as in pattern #8 except the 3 plants present are 'slightly' misplaced.	5 ½
10	40	20,000	Similar to pattern #8, except the plants present are even more inaccurately spaced within groups than in pattern #9.	5 ½
11	70	36,000	The pattern is 8 plants within 32 in., a 32 in. gap, and 5 plants within 12 in. Plants within each group are not spaced equally.	5 ½
12	40	20,000	Similar to pattern #11. Five plants within 28 in., a gap of 48 in., and 4 plants within 12 in. Plants within each group are not spaced equally.	5 ½

[1] These are the actual or assigned spacing modes used as the basis of the plant spacing accuracy parameter, "mode ±½ in.", used in Tables 2 and 3.

Table 2. Yield and measured plant spacing parameters averaged over the four sites which included spacing patterns 1 through 10 only.

Site No. (-yr)	Simulated Field Emergence [1] (%)	Spacing Pattern No. (-H/L)[2]	Mode Spacing ±½ in. (%)	Large Spacings >16.5 in. (%)	Root Tare (%)	Percent Sugar (%)	Root Yield (%)	Sugar Yield (lb/A)
1 - '96			33.4 a[3]	16.6 c	9.4 c	15.6 a	27.8 c	8,660 bc
2 - '97			32.3 a	15.7 c	12.3 a	14.2 c	31.6 b	9,000 b
3 - '97			26.7 c	21.5 b	12.9 a	14.9 b	27.9 c	8,310 c
4 - '98			28.9 b	23.2 a	11.2 b	15.5 a	35.6 a	11,000 a
	High		34.0 a	6.7 b	12.1 a	15.1 a	31.1	9,400 a
	Low		26.7 b	31.8 a	10.8 b	15.0 b	30.4	9,090 b
							n.s.	
		1 - H	51.9 a	2.6 f	11.9 ab	15.0	31.1	9,280
		2 - H	35.8 d	6.2 e	11.6 ab	15.2	30.9	9,370
		3 - H	44.7 c	10.8 d	12.0 ab	15.1	31.6	9,560
		4 - H	23.5 e	7.1 e	12.8 a	15.2	30.0	9,130
		5 - H	13.9 g	6.9 e	12.0 ab	15.2	32.0	9,660
		6 - L	47.8 b	16.0 c	9.8 c	14.9	30.9	9,210
		7 - L	17.0 f	29.7 b	11.1 bc	15.0	31.1	9,280
		8 - L	36.7 d	37.8 a	11.1 bc	14.9	29.6	8,830
		9 - L	16.9 f	38.1 a	11.3 b	15.1	29.3	8,840
		10 - L	15.1 fg	37.5 a	10.7 bc	15.0	30.9	9,270
						n.s.	n.s.	n.s.

[1] 'High' emergence indicates those spacing patterns with a target of 36,000 plants/A and 'low' emergence designates spacing patterns with target plant population of 20,000 plants/A.
[2] 'H' designates simulated high emergence patterns ; 'L' designates simulated low emergence patterns.
[3] Mean values with the same letter within a column and within a comparison grouping are not statistically different at the 0.05 level of significance.

Table 3. Yield and measured plant spacing parameters averaged over the three sites which included spacing patterns 1 through 12.

Site No. (-yr)	Simulated Field Emergence[1] (%)	Spacing Pattern No. (-H/L)[2]	Mode Spacing ±½ in. (%)	Large Spacings >16.5 in. (%)	Root Tare (%)	Percent Sugar (%)	Root Yield (%)	Sugar Yield (lb/A)
2 - '97			28.7 a[3]	15.5 c	12.2 a	14.3 c	31.1 b	8,890 b
3 - '97			23.9 c	20.1 b	12.8 a	14.9 b	27.7 c	8,260 c
4 - '98			25.8 b	22.4 a	11.2 b	15.4 a	34.8 a	10,750 a
	High		29.9 a	7.7 b	12.6 a	14.9	31.9 a	9,520 a
	Low		22.3 b	31.2 a	11.6 b	14.8	30.5 b	9,080 b
						n.s.		
		1 - H	48.5 a	3.2 h	12.6 ab	14.7	32.8 abc	9,630 ab
		2 - H	34.3 c	7.2 g	12.2 b	15.0	31.5 abcd	9,460 abc
		3 - H	44.2 b	11.3 e	12.4 ab	15.0	33.0 ab	9,940 a
		4 - H	22.5 d	6.7 g	13.9 a	15.0	30.9 bcd	9,310 abc
		5 - H	14.7 f	8.2 fg	12.6 ab	14.9	33.6 a	10,000 a
		6 - L	45.9 ab	17.8 d	10.3 c	14.7	31.4 abcd	9,270 abc
		7 - L	17.3 e	30.3 b	12.0 b	14.8	31.5 abcd	9,360 abc
		8 - L	34.4 c	39.3 a	11.9 bc	14.8	30.6 cd	9,030 bcd
		9 - L	16.0 ef	39.6 a	12.1 b	14.9	30.3 d	9,030 bcd
		10 - L	15.3 ef	38.1 a	11.2 bc	14.8	31.6 abcd	9,350 abc
		11 - H	15.5 ef	9.7 ef	11.1 bc	14.8	29.7 de	8,780 cd
		12 - L	4.8 g	22.0 c	12.1 b	15.1	27.8 e	8,430 d
						n.s.		

[1] 'High' emergence indicates those spacing patterns with a target of 36,000 plants/A and 'low' emergence designates spacing patterns with target plant population of 20,000 plants/A.
[2] 'H' designates simulated high emergence patterns; 'L' designates simulated low emergence patterns.
[3] Mean values with the same letter within a column and within a comparison grouping are not statistically

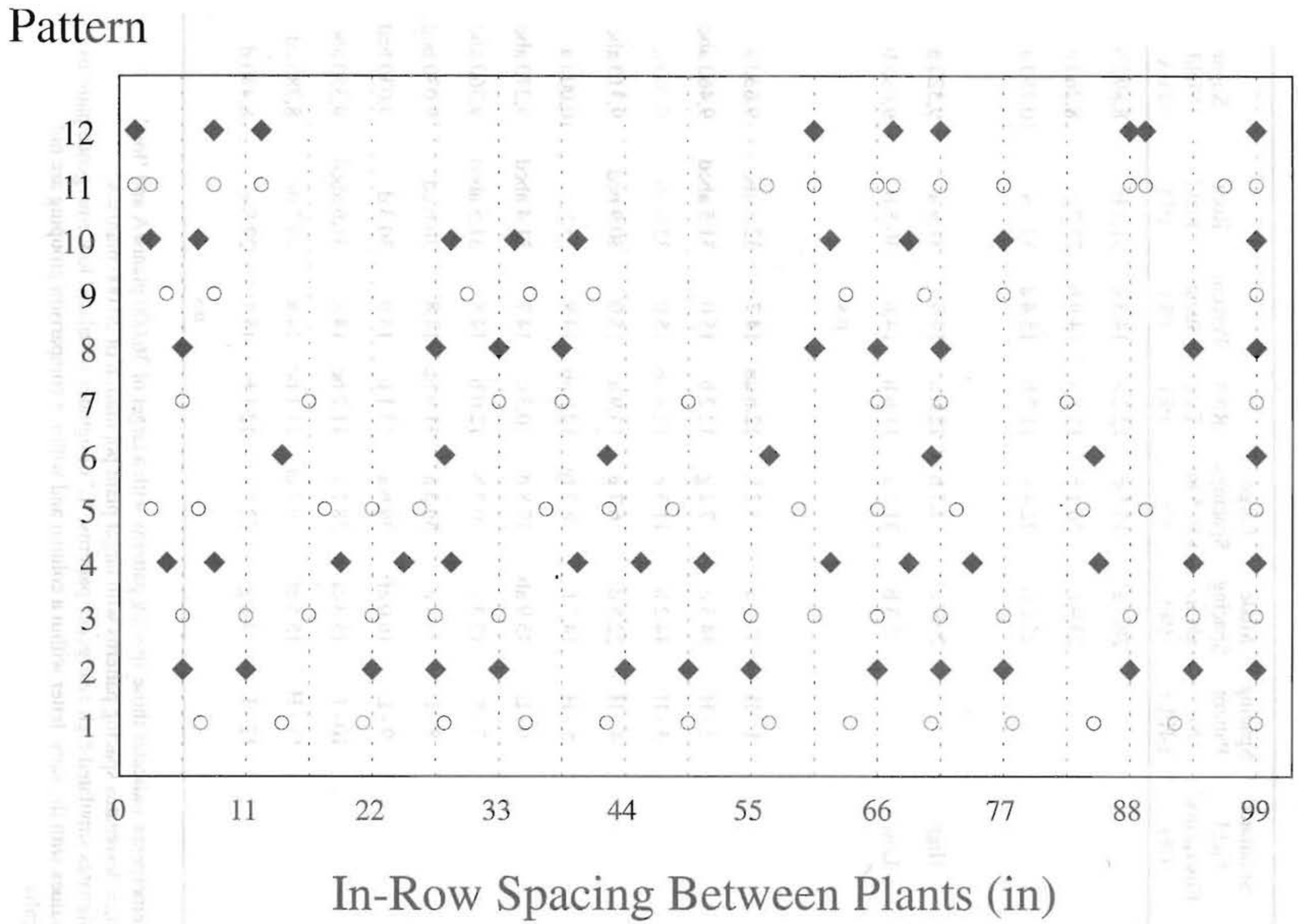

Figure 1. Target in-row spacing configurations for the twelve patterns.

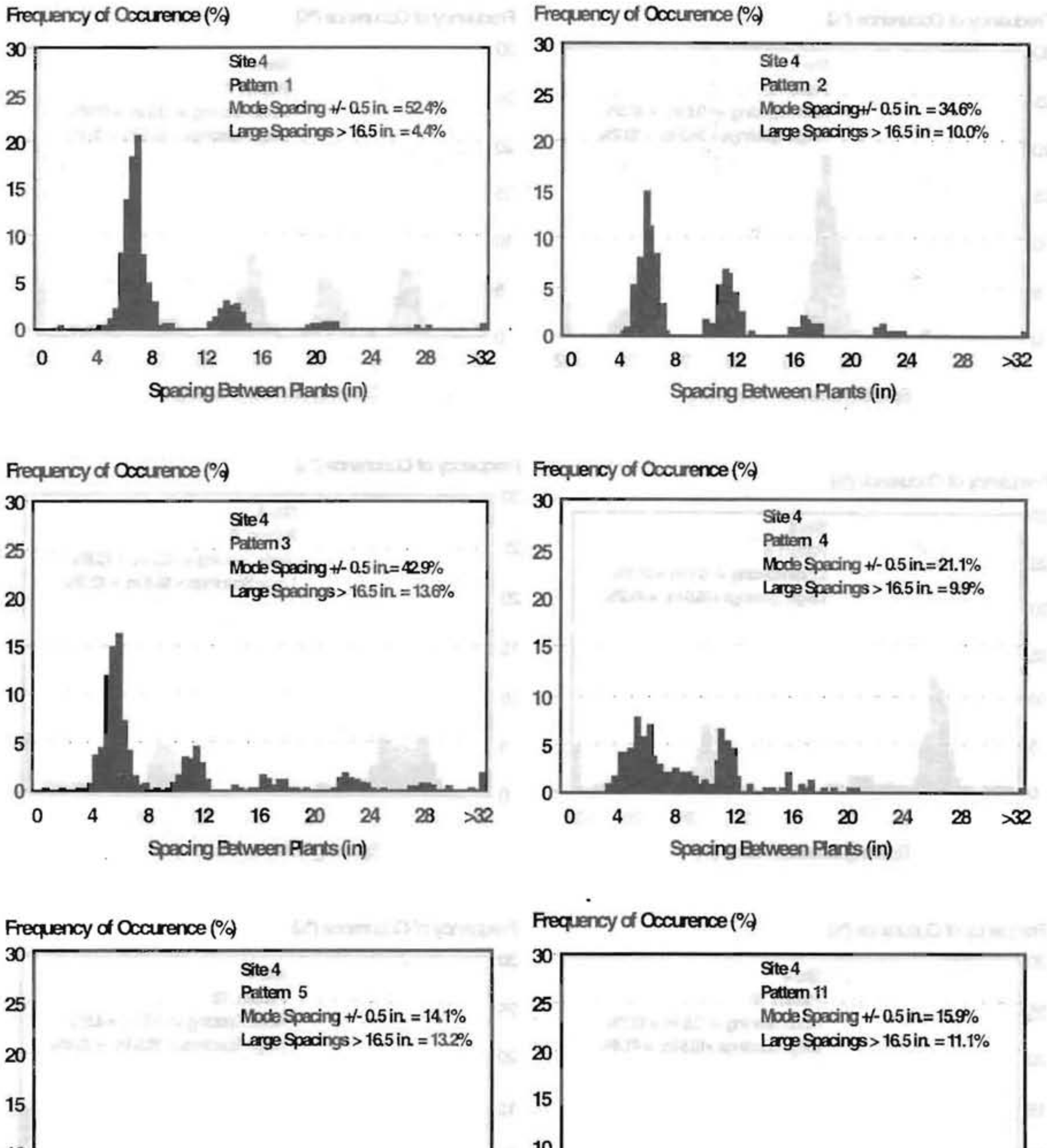

Figure 2. Frequency diagrams of the high population patterns 1-5 & 11 from site 4. Mode Spacing +/- 0.5 in. is the percentage of total plant spacings that fell within +/- 0.5 inch of the mode spacing. Large Spacings > 16.5 in. is the percentage of total plant spacings that are greater than 16.5 inches.

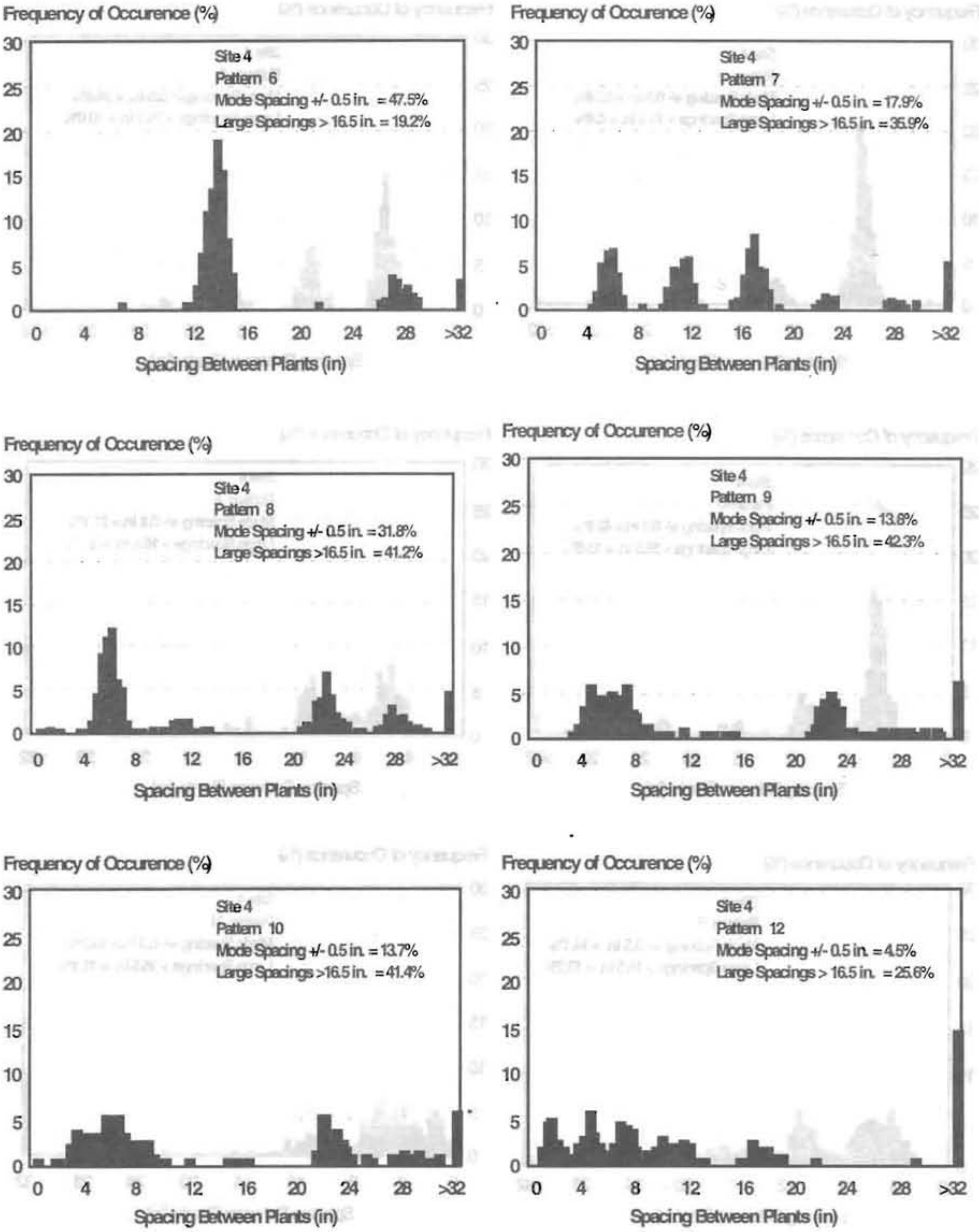

Figure 3. Frequency diagrams of the low population patterns 6-10 & 12 from site 4. Mode Spacing +/- 0.5 in. is the percentage of total plant spacings that fell within +/- 0.5 inch of the mode spacing. Large Spacings > 16.5 in. is the percentage of total plant spacings that are greater than 16.5 inches.