Project Number: 84-J2

Project Title: Measurement of Nut Detachment Forces Before and After Harvest

Project Leader: H. E. Studer 84-J2

Objectives of Research:

Some almond nuts remain on the trees after mechanical harvesting. Apart from the resulting economic loss, these nuts can serve as overwintering sites for the navel orange worm. Follow-up nut removal by means of tree shaking in the winter or manual poling are often practiced. This project seeks to determine why these nuts remain after shake harvest: are they simply bonded very strongly to the tree, or is the problem related to tree response to shaker vibration?

Procedure:

The project was carried out with the cooperation of Mr. Sam Lewis, a grower in Chico, CA., who made available his orchards and a self-propelled pruning tower. Varieties studied were Nonpareil, Merced, Mission, Harvey and Drake. A Hunter L-10 M hand held mechanical force gauge was used to measure the tensile forces required to manually pull almonds from the branches. The pruning tower allowed testing in the upper sections of the trees, although the tops of the trees were generally too high to be accessible.

Detachment forces were measured the day before harvest on several trees (generally 4). Approximately 400 pre-harvest measurements were made for each tree. Post harvest measurements were made immediately after harvest for those nuts which remained on these same trees. (All measurements for any given tree were made within a period of two days). Since the number of nuts left after harvest was small for some varieties, additional trees were included in the after harvest sampling in order to increase the number of post harvest detachment force observations.

The data were collected by 2 people over a period of six weeks between August 27 and October 6. The observations were recorded in one of 4 categories which described the color and condition of the stem and hull. The categories were identified as shown in Table 1.

Table 1. Distinguishing features of nut categories.

Nut category =	Stem color +	Hull color	
GB	G	B	hull split
GG	G	G	hull split
BB	B	B	hull split
BC	B	C	hull closed

G = Green
B = Brown

Results

The data, without regard for stem-hull characteristics, is presented in Figures 1-23, each of which consists of a histogram accompanied by a frequency table. Figure 1 shows the data for Nonpareil trees sampled during the first week, for which nut detachment force was measured both before and after harvest. Figure 2 displays the data for Nonpareil during the first week for which forces were measured on trees only after harvest. Figure 16 presents all of the Nonpareil data where both before and after measurements were

made, and Figure 19 represents all Nonpareil data collected during the season. A similar set of tables is provided for each of the other varieties. Figure 23 presents all of the detachment force data collected for all varieties.

At the top of the frequency table in each of Figures 1-23 is shown a value of N, the number of observations represented by the plots; the mean value of the detachment forces (in pounds); and the variance of these observations. The frequency table lists the percent of total observations in given intervals, usually 0.2 lbs. For example, in Figure 1, out of a total of 1585 measurements made before harvest, 495 or 31.2% were equal to or less than 0.2 lbs and 68.8% of the total observations were greater than 0.2 lbs. The maximum observed value among these 1585 observations was 4.1 lbs, shown at the bottom of the frequency table. The histogram is a graphical representation of the data in the accompanying frequency table.

A summary of numbers of observations, means and variances for each of the tests is shown in Table 2, where each of the data sets is associated with one of the Figures 1-23. The column headed "mean ratio" shows the ratio of the after harvest mean detachment force to the before harvest mean detachment force. The column headed B represents the percentage of the "after harvest" observations that had detachment force values smaller than the mean detachment force of the "before harvest" observations. Each value of B was calculated by linear interpolation in the corresponding "after harvest" frequency table. For example, consider the histogram for the data set "all Nonpareil, before and after", shown in Figure 16. The "before harvest" mean is 0.45 lbs. B is calculated as follows:

$$B = \frac{13.4\ (0.45 - 0.40)}{0.6 - 0.4} + (13.0 + 18.5)$$

$$= 35\%$$

Table 3 displays the mean detachment force values and the number of observations for each of the categories describing the stem-hull characteristics, for each variety measured <u>both</u> before and after harvest. Table 4 provides additional summaries of the two Mission data sets. Table 5 provides additional summaries for all data sets in which observations in the GG category were virtually nonexistent.

Discussion:

The data summaries presented in Table 2 show that the mean post harvest detachment force was, without exception, higher than the corresponding pre-harvest mean force. The values of mean ratio range from 1.58 for Harvey to 4.83 for one of the Nonpareil data sets. All values are greater than 2 with the exception of Harvey. Moreover, an inspection of Figures 1-23 shows that the maximum values observed in the "before and after" data sets occurred, with one exception, in the after harvest data sets.

The values of B, also listed in Table 2, show that while the mean post harvest detachment forces may be large, a substantial number of nuts remain on the tree after shaking which have, individually, relatively low detachment force values. For example, the data set "Nonpareil, all data" is characterized by a value of B = 30%, and this value of B is represented by the cross hatched area under the curve in Figure 16.

The "before harvest" and "after harvest" nut populations also have variances (S^2) which are very different as evident in Table 2. As expected, the after harvest nut populations are more spread out. Both populations, however, are highly skewed to the right and very definitely non-normal.

The data in Table 3 shows that, with a single exception, the mean detachment force values associated with each of the nut categories identified in Table 1 are greater for those measured after harvest than for those measured before harvest. It appears that the action of the harvester is selective, and irrespective of nut type, nut detachment is sensitive to nut bonding force. Table 3 also shows that the largest mean detachment force values for the categories listed were generally those exhibited by the BC nut category (brown stem with non-split hull). Table 5 shows that the BC category represented a large percentage of the after-harvest nut population for data sets Nonpareil week 1 and week 3, and also for Merced.

A separate summary of the two Mission data set is shown in Table 4. The nut category GG was rarely represented in the tests except in the "Mission-week 5" data set. The trees in the "Mission-week 6" data set were drier, and most of the nuts were represented by the BB category, with very low nut detachment forces. Very few of the Mission-week 5 observations fell in the BB category. Rather, the observations were primarily represented by GB, with a substantial fraction in GG. The nuts in the GG category have split hulls but drying of the stems and hulls is incomplete. It should also be noted that the mean detachment forces for these "green" GG and GB nuts are comparable to those representing the BC category, this observation applying to both the before and after harvest nut populations.

Conclusions:

This study of almond nut detachment forces has clearly shown that nut removal from the tree at harvest was influenced by the magnitude of the force bonding the nuts to their stems. Nut bonding forces varied over a wide but similar range for all varieties tested, and the mean forces were surprisingly similar where nut conditions were common. The nuts which remained on the trees after harvest were invariably characterized by a higher average bonding force than those of the pre-harvest population. However, a substantial fraction of those nuts remaining on the trees after shaking exhibited bonding forces which were very small. This fact resulted in a substantially higher variance for the "after harvest" measurements. Consequently the values of mean ratio are actually misleading, and tend to underestimate the difficulty of the problem of removing the nuts by shaking.

The results suggest that incomplete nut detachment is due in part to shaker design and operation, but nonuniform tree response to the vibration is also a factor. Moreover, while improvements in nut detachment efficiency may be possible, the existence of nuts with very high bonding forces suggests that the mummy nut problem will not likely be resolved by changes in current shaker design and operation alone.

Table 2. Summary of 1984 almond nut detachment force data. (Force measured in pounds).

Data set	Week No.	No. Trees	Before Harvest N	Before Harvest Ave. force	Before Harvest S^2	After Harvest N	After Harvest Ave. force	After Harvest S^2	Mean Ratio	B, %
Nonpareil, before and after	1	4	1585	0.52	0.21	75	2.05	8.53	3.94	--
" only after	1	8	--	--	--	245	1.48	4.45	--	--
" before and after	2	5	1756	0.47	0.19	446	0.95	1.42	2.02	--
" only after	2	1	--	--	--	13	0.85	1.28	--	--
" before and after	3	4	1596	0.36	0.10	201	1.74	2.18	4.83	--
" only after	3	2	--	--	--	70	1.78	6.76	--	--
Merced, before and after	3	4	1600	0.42	0.10	244	1.57	2.42	3.73	17
" only after	3	1	--	--	--	30	1.52	4.70	--	--
Mission, before and after	5	3	1234	1.27	1.04	343	2.16	1.75	1.70	--
" only after	5	4	--	--	--	304	2.24	7.14	--	--
" before and after	6	2	811	0.24	0.03	97	0.60	0.63	2.50	--
" only after	6	2	--	--	--	110	0.91	1.55	--	--
Harvey, before and after	5	1	405	0.50	0.10	18	0.79	0.28	1.58	39
Drake, before and after	6	4	1675	0.43	0.14	159	1.35	1.36	3.14	24
" only after	6	2	--	--	--	573	1.90	7.20	--	--
All Nonpareil, before and after	--	13	4937	0.45	0.17	722	1.28	2.34	2.84	35
All Mission, before and after	--	5	2045	0.87	0.89	440	1.82	1.92	2.09	31
Nonpareil, all data	--	24	4937	0.45	0.17	1050	1.35	3.12	3.00	30
Merced, all data	--	5	1600	0.42	0.10	274	1.56	2.66	3.71	17
Mission, all data	--	11	2045	0.87	0.89	854	1.85	3.89	2.13	30
Harvey, all data	--	1	405	0.50	0.10	18	0.79	0.28	1.58	39
Drake, all data	--	6	1675	0.43	0.14	732	1.78	5.98	4.13	20
All varieties, before and after	--	27	10662	0.52	0.32	1583	1.48	2.17	2.84	31
All varieties, all data	--	47	10662	0.52	0.32	2928	1.62	4.05	3.11	26

$\bar{x} = 2.87$

Table 3. Number of observations per tree and mean nut detachment force, $\bar{X}$, for each nut category for each variety. (includes only "before and after" data).

		Before Harvest				After Harvest			
Data set	Tree	GB	GG	BB	BC	GB	GG	BB	BC
Nonpareil-week 1	1	95	45	242	6	0	0	11	16
	2	98	1	294	3	2	1	7	5
	3	108	7	285	2	0	0	2	1
	4	23	0	372	2	0	0	21	9
	$\bar{X}$	0.7	1.3	0.4	1.7	--	--	1.3	3.1
Nonpareil-week 2	1	12	0	355	3	1	0	144	8
	2	1	0	389	6	0	0	113	3
	3	2	0	373	12	0	1	118	8
	4	0	0	203	0	0	0	32	5
	5	3	0	396	1	0	0	12	1
	$\bar{X}$	0.3	--	0.4	2.0	--	--	0.9	2.3
Nonpareil-week 3	1	5	4	386	1	2	3	31	1
	2	4	0	372	24	1	0	52	12
	3	1	0	385	14	0	0	6	84
	4	1	0	390	9	0	0	4	5
	$\bar{X}$	0.3	--	0.3	1.2	--	--	1.1	2.4
Merced-week 3	1	233	0	162	5	6	0	26	16
	2	321	0	74	4	5	0	8	4
	3	288	0	101	9	26	2	59	39
	4	359	0	40	1	14	0	28	8
	$\bar{X}$	0.4	--	0.5	0.8	1.1	--	1.4	2.3
Mission-week 5	1	199	180	2	17	53	104	6	1
	2	314	80	7	3	63	61	12	7
	3	333	38	10	44	8	12	2	4
	$\bar{X}$	1.1	1.8	0.4	1.3	2.1	2.3	1.3	2.1
Mission-week 6	1	51	0	349	1	0	0	0	0
	2	35	0	373	0	6	38	45	4
	$\bar{X}$	0.3	--	0.2	0.2	1.9	0.5	0.6	0.4
Harvey-week 5	1	3	0	400	2	0	0	10	2
	$\bar{X}$	0.4	--	0.5	0.8	--	--	0.8	1.8
Drake-week 6	1	18	0	392	3	5	0	9	1
	2	12	0	408	1	14	3	45	2
	3	19	0	400	0	3	0	25	2
	4	19	0	390	6	0	0	11	7
	$\bar{X}$	.4	--	.4	1.1	1.6	--	1.3	1.4

Table 4. Summary of nut detachment force observations for each nut category for Mission variety measured in two different orchards at Chico, CA.

		Before Harvest					After Harvest				
Week No.	Tree No.	N	GG	GB	BB	BC	N	GG	GB	BB	BC
5	1	398	180	199	2	17	164	104	53	6	1
	2	404	80	314	7	3	143	61	63	12	7
	3	425	38	333	10	44	26	12	8	2	4
Total		1227	298	846	19	64	333	177	124	20	12
% of total			68.9	24.3	1.5	5.2		53.2	37.0	6.0	3.6
Mean force, pounds			1.1	1.8	0.4	1.3		2.3	2.2	1.3	2.1
Overall mean force, pounds			1.3					2.2			
6	1	401	0	51	349	1	0	0	0	0	0
	2	408	0	35	373	0	93	38	6		4
Total		809	0	86	722	1	93	38	6	45	4
% of total			0	10.6	89.2	0.1		40.9	6.5	48.4	4.3
Mean force, pounds			--	0.3	0.2	0.2		0.5	1.9	0.6	0.4
Overall mean force, pounds			0.2					0.6			

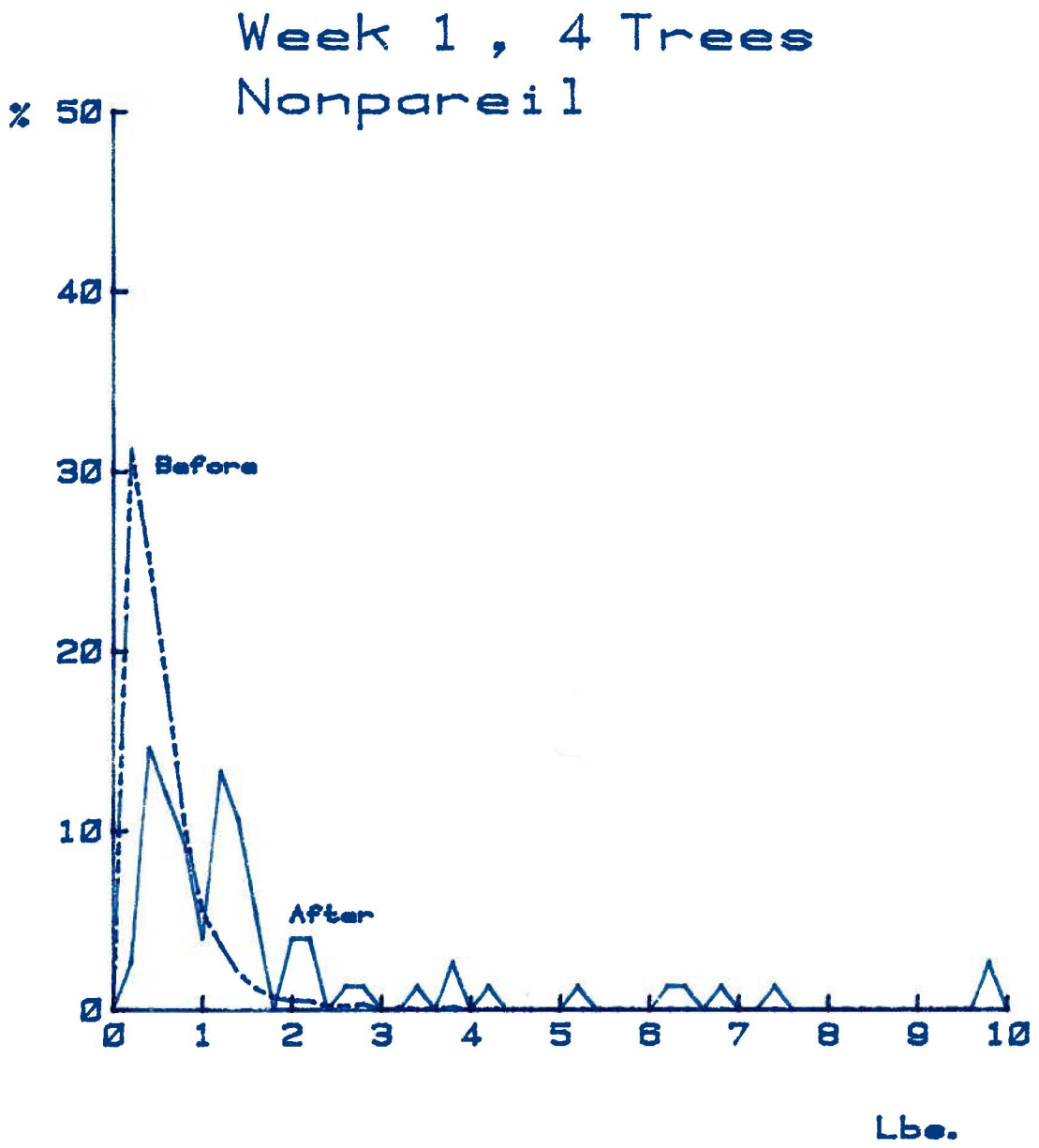
Table 5. Percentage of nuts represented by various nut categories.[1/]

	Before Harvest					After Harvest				
			Nut Category					Nut Category		
Data Set	N_G[2/]		GB	BB	BC	N_a[2/]		GB	BB	BC
Nonpareil-week 1	1530	%	21.2	80.0	0.9	74	%	2.7	55.4	41.9
		$\bar{X}$[3/]	0.7	0.4	1.7		$\bar{X}$	0.9	1.3	3.1
Nonpareil-week 2	1756	%	1.0	97.7	1.3	445	%	0.2	94.1	5.6
		$\bar{X}$	0.3	0.4	2.0		$\bar{X}$	0.4	0.9	2.3
Nonpareil-week 3	1592	%	0.7	96.3	3.0	198	%	1.5	47.0	51.5
		$\bar{X}$	0.3	0.3	1.2		$\bar{X}$	0.5	1.1	2.4
Merced-week 3	1597	%	75.2	23.6	1.2	239	%	21.3	50.6	28.0
		$\bar{X}$	0.4	0.5	0.8		$\bar{X}$	1.2	1.4	2.3
Mission-week 6	809	%	10.6	89.0	0.1	55	%	10.9	81.8	7.3
		$\bar{X}$	0.3	0.2	0.2		$\bar{X}$	1.9	0.6	0.4
Harvey-week 5	405	%	0.7	98.8	0.5	12	%	0.0	83.4	16.6
		$\bar{X}$	0.4	0.5	0.8		$\bar{X}$	--	0.8	1.8
Drake-week 6	1668	%	4.1	95.3	0.6	124	%	17.7	72.6	9.7
		$\bar{X}$	0.4	0.4	1.1		$\bar{X}$	1.6	1.3	1.4

[1/]This table is based on only "before and after" data sets; it does not include Mission-week6; and all GG observations in these data sets was first subtracted out.

[2/]N_G = No. observations "before"; N_a = No. observations "after".

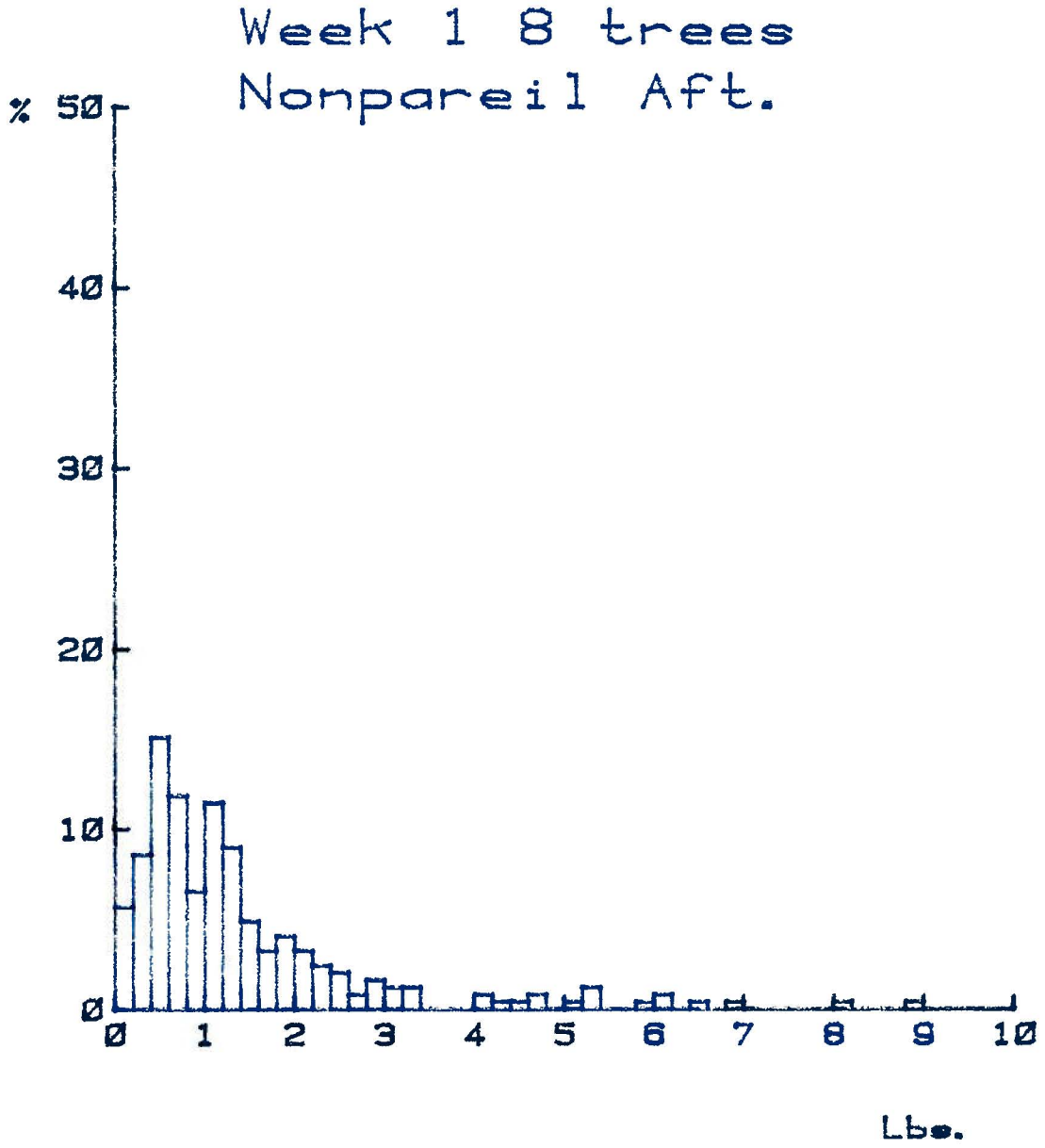
[3/]$\bar{X}$ = mean nut detachment force in the given category.



	Before	After
Number	1585	75
Mean	.517	2.0508
Variance	.2081	8.5338

Lbs.	Num	%	Cum	Num	%	Cum
.2	495	31.2	68.8	2	2.8	97.4
.4	400	25.2	43.6	11	14.8	82.7
.6	287	18.1	25.5	9	12	70.7
.8	163	10.2	15.2	7	8.3	61.4
1	88	5.4	9.8	3	4	57.4
1.2	58	3.6	6.1	10	13.3	44
1.4	33	2	4	8	10.8	33.4
1.6	18	1.1	2.8	4	5.3	28
1.8	11	.8	2.1	0	0	28
2	8	.5	1.6	3	4	24
2.2	8	.5	1.1	3	4	20
2.4	3	.1	.9	0	0	20
2.6	3	.1	.7	1	1.3	18.7
2.8	5	.3	.4	1	1.3	17.4
3.2	2	.1	.3	0	0	17.4
3.4	0	0	.3	1	1.3	16
3.6	1	0	.2	0	0	16
3.8	2	.1	.1	2	2.6	13.4
4.2	1	0	0	1	1.3	12
5.2	0	0	0	1	1.3	10.7
6.2	0	0	0	1	1.3	9.4
6.4	0	0	0	1	1.3	8
6.6	0	0	0	1	1.3	6.7
7.4	0	0	0	1	1.3	5.4
8.6	0	0	0	2	2.6	2.7
10	0	0	0	2	2.6	0
Maximum		4.1			12.2	

Figure 1 . Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Nonpareil almonds on 08/27/84.

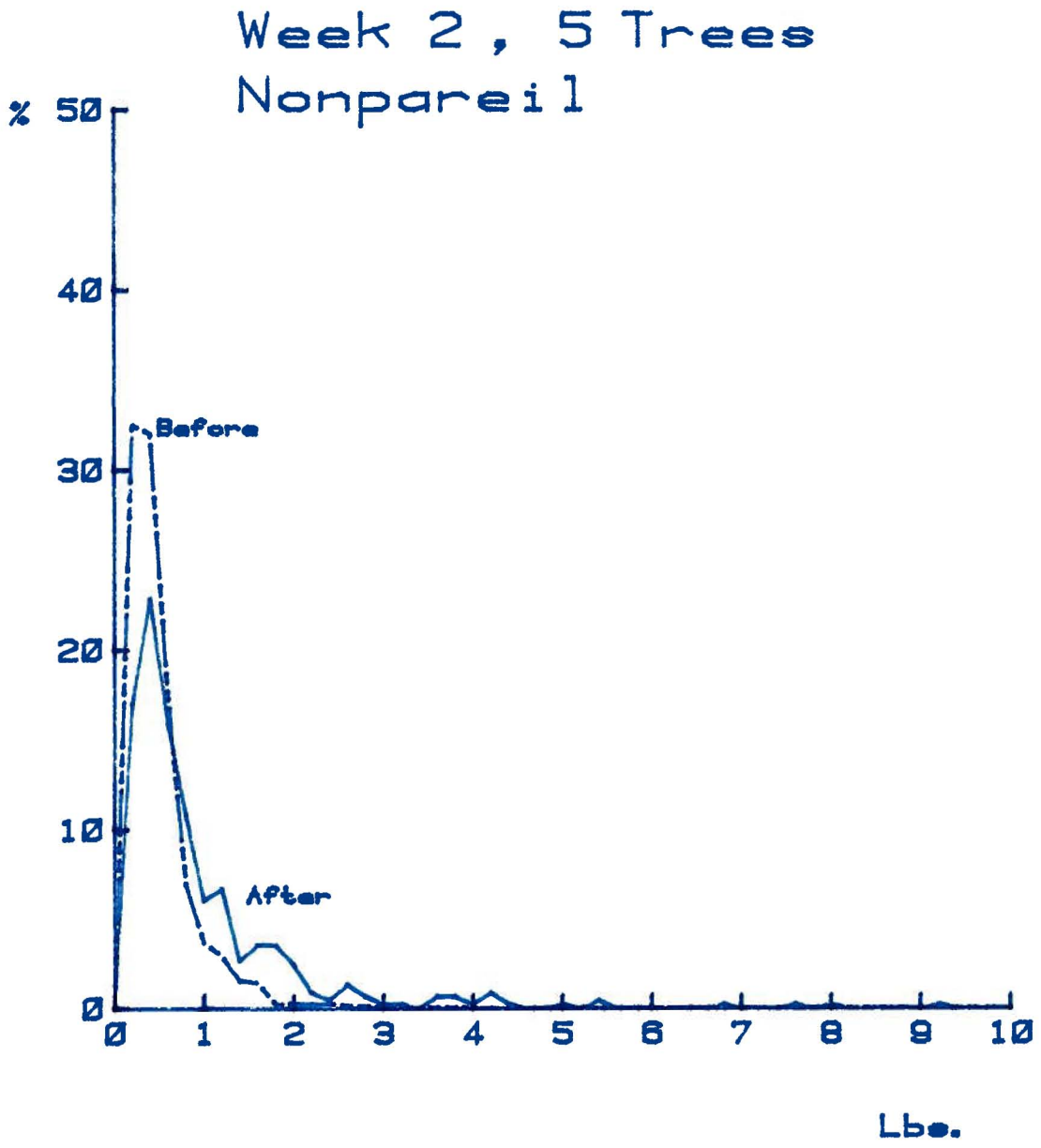


All Types

	After
Number	245
Mean	1.4838
Variance	4.448

Lbs.	Num	%	Cum	Num	%	Cum
.2				14	5.7	84.3
.4				21	8.5	85.8
.6				37	15.1	70.7
.8				29	11.8	58.8
1				18	8.5	52.3
1.2				28	11.4	40.8
1.4				22	8.8	31.8
1.6				12	4.8	27
1.8				8	3.2	23.7
2				10	4	19.8
2.2				8	3.2	16.4
2.4				6	2.4	13.8
2.6				5	2	11.8
2.8				2	.8	11.1
3				4	1.6	8.4
3.2				3	1.2	6.2
3.4				3	1.2	7
4.2				2	.8	6.2
4.4				1	.4	5.6
4.6				1	.4	5.3
4.8				2	.8	4.5
5.2				1	.4	4.1
5.4				3	1.2	2.9
6				1	.4	2.5
6.2				2	.8	1.7
6.6				1	.4	1.3
7				1	.4	.9
8.2				1	.4	.4
9				1	.4	0
Maximum					8.9	

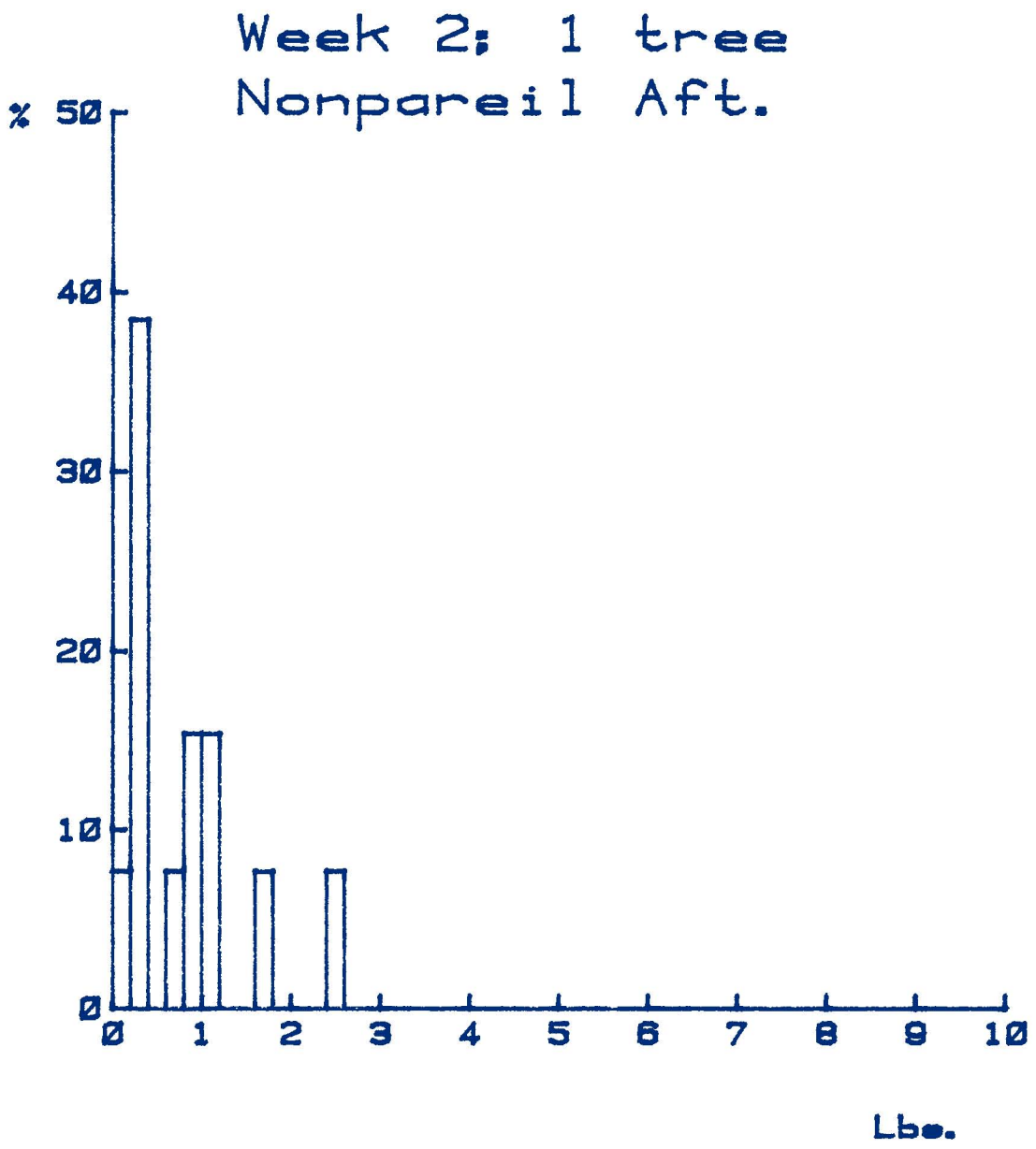
Figure 2 . Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Nonpareil almonds on 08/29/84.



	Before	After
Number	1758	448
Mean	.4857	.9495
Variance	.1882	1.4185

Lbs.	Num	%	Cum	Num	%	Cum
.2	570	32.4	67.6	76	17	83
.4	562	32	35.6	102	22.8	60.1
.6	305	17.3	18.2	71	15.8	44.2
.8	122	6.8	11.3	48	10.7	33.4
1	65	3.7	7.6	27	6	27.4
1.2	52	2.9	4.6	30	6.7	20.7
1.4	27	1.5	3.1	12	2.6	18
1.6	25	1.4	1.6	16	3.5	14.4
1.8	4	.2	1.4	16	3.5	10.8
2	5	.2	1.1	11	2.4	6.3
2.2	4	.2	.9	4	.8	7.4
2.4	5	.2	.6	2	.4	7
2.6	2	.1	.5	6	1.3	5.6
2.8	2	.1	.4	3	.6	5
3	1	0	.3	1	.2	4.7
3.2	1	0	.3	1	.2	4.5
3.6	1	0	.2	3	.6	3.9
3.8	1	0	.2	3	.6	3.2
4	1	0	.1	1	.2	3
4.2	0	0	.1	4	.8	2.1
4.4	0	0	.1	1	.2	1.8
5	0	0	.1	1	.2	1.6
5.4	0	0	.1	2	.4	1.2
6.8	0	0	.1	1	.2	.8
7.8	0	0	.1	1	.2	.7
8	1	0	0	1	.2	.5
9.2	0	0	0	1	.2	.3
10	0	0	0	1	.2	0
Maximum		8			11.1	

Figure 3 . Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Nonpareil almonds on 09/04/84.

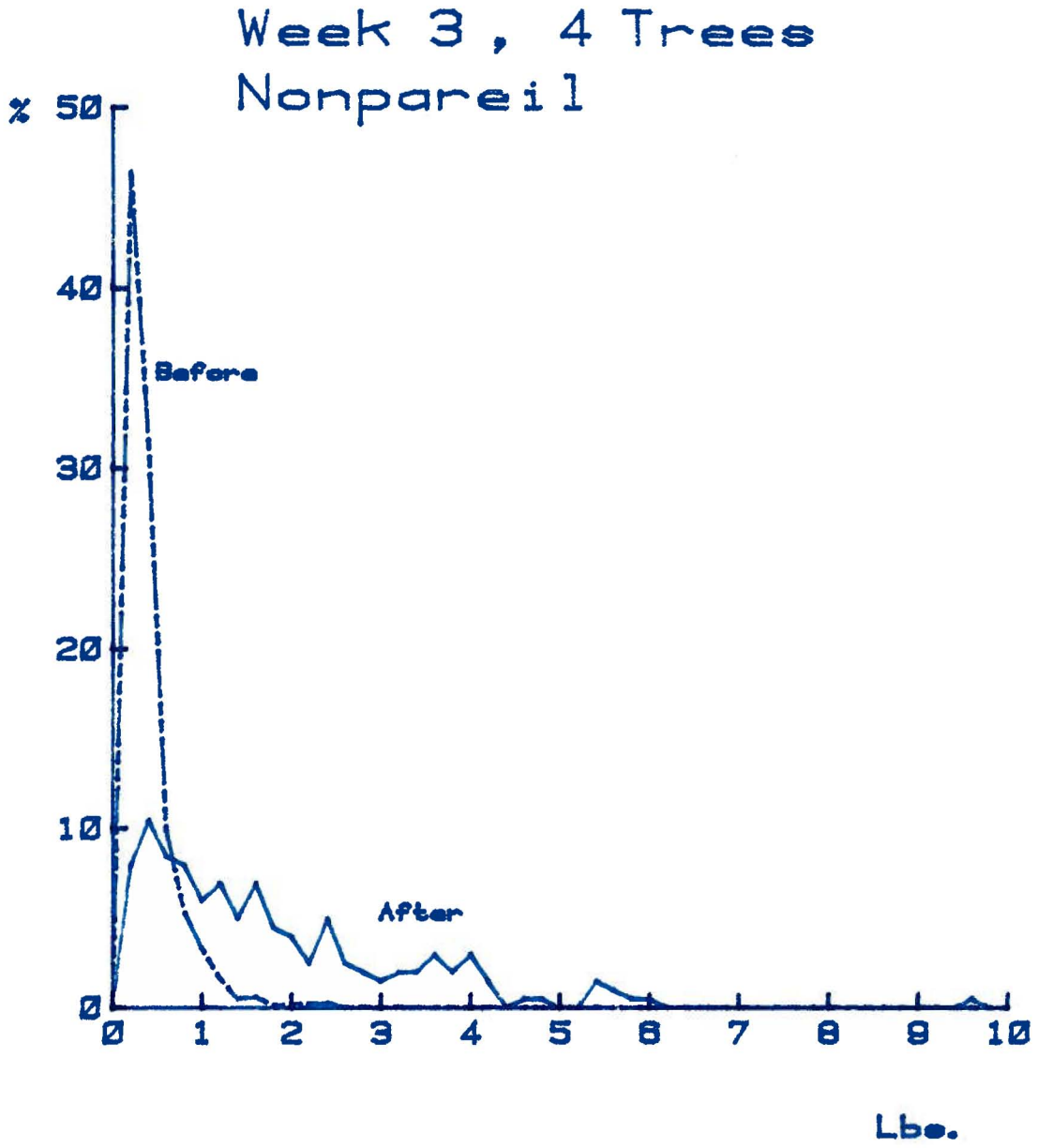


All Types

	After
Number	13
Mean	.8538
Variance	1.2804

Lbs.	Num	%	Cum	Num	%	Cum
.2				1	7.6	92.3
.4				5	38.4	53.8
.6				1	7.6	46.2
1				2	15.3	30.8
1.2				2	15.3	15.4
1.8				1	7.6	7.7
2.6				1	7.6	0
Maximum					2.5	

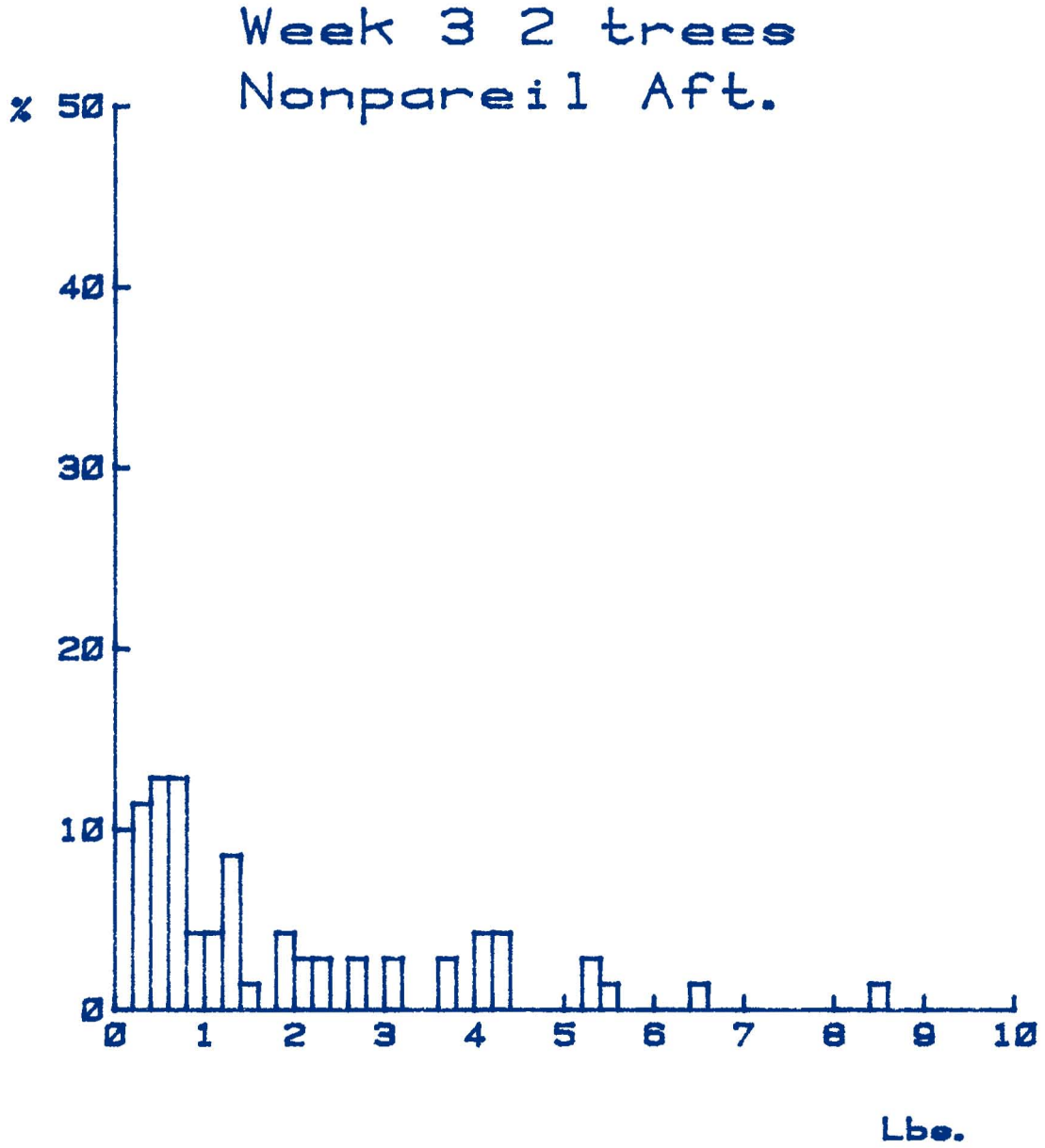
Figure 4 . Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Nonpareil almonds on 09/05/84.



	Before	After
Number	1598	201
Mean	.3807	1.7412
Variance	.0992	2.1812

Lbs.	Num	%	Cum	Num	%	Cum
.2	743	46.5	53.5	16	7.9	92.1
.4	498	31.2	22.3	21	10.4	81.6
.6	156	9.8	12.4	17	8.4	73.2
.8	88	5.3	7	16	7.9	65.2
1	53	3.3	3.7	12	5.9	59.2
1.2	26	1.6	2	14	6.9	52.3
1.4	8	.5	1.5	10	4.9	47.3
1.6	10	.6	.9	14	6.9	40.3
1.8	2	.1	.8	9	4.4	35.9
2	3	.1	.8	8	3.9	31.9
2.2	3	.1	.4	5	2.4	29.4
2.4	4	.2	.2	10	4.9	24.4
2.6	0	0	.2	5	2.4	21.9
2.8	1	0	.1	4	1.9	19.9
3	0	0	.1	3	1.4	18.4
3.2	1	0	0	4	1.9	16.5
3.4	0	0	0	4	1.9	14.5
3.6	0	0	0	6	2.9	11.5
3.8	0	0	0	4	1.9	9.5
4	0	0	0	6	2.9	6.5
4.2	0	0	0	3	1.4	5
4.4	0	0	0	1	.4	4.5
4.6	0	0	0	1	.4	4
5.4	0	0	0	3	1.4	2.5
5.6	0	0	0	2	.9	1.5
5.8	0	0	0	1	.4	1
6	0	0	0	1	.4	.5
8.6	0	0	0	1	.4	0
Maximum		3.2			9.8	

Figure 5 . Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Nonpareil almonds on 09/10/84.

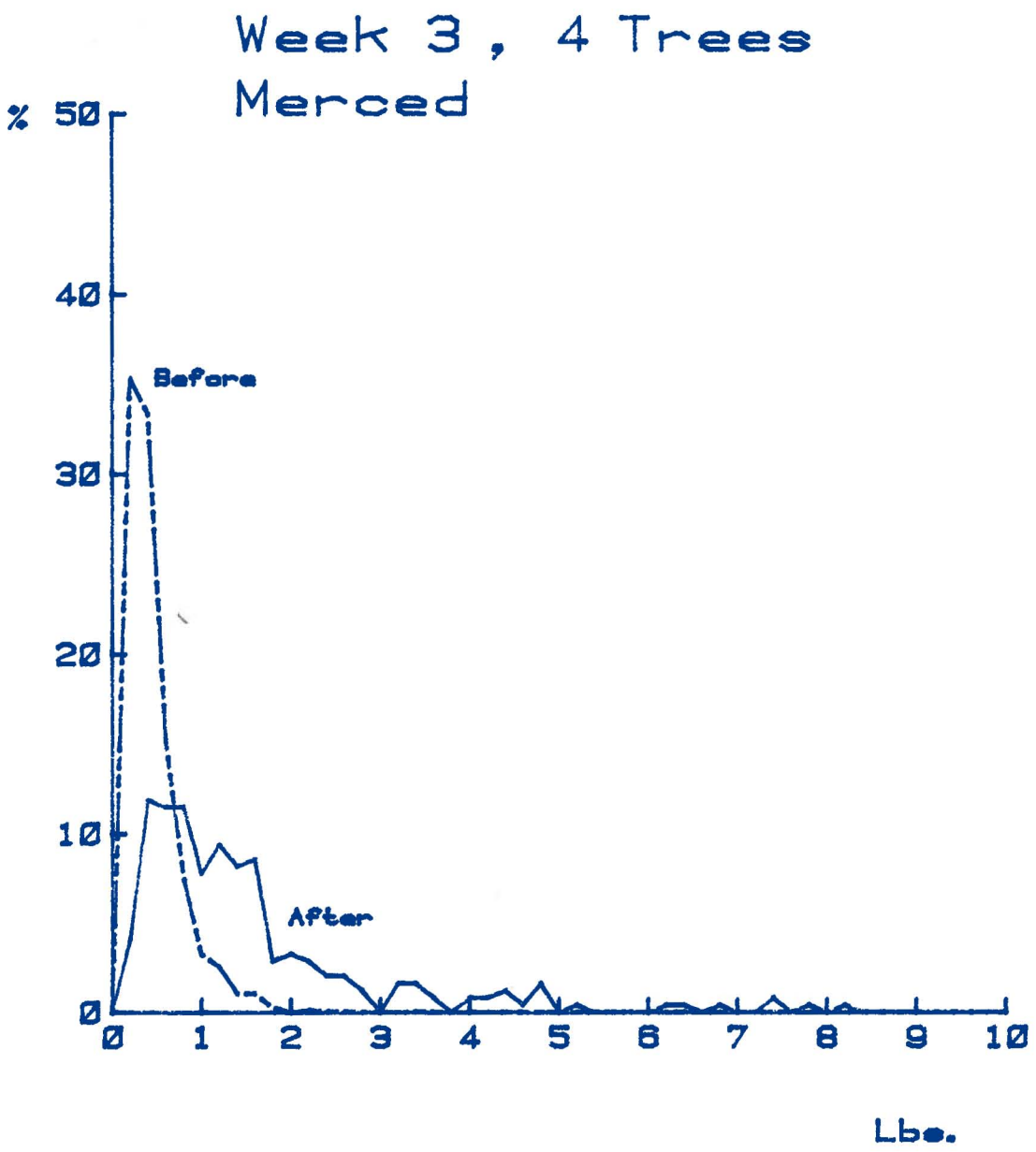


All Types

	After
Number	70
Mean	1.7814
Variance	6.784

Lbs.	Num	%	Cum	Num	%	Cum
.2				7	10	90
.4				8	11.4	78.6
.6				9	12.8	65.8
.8				9	12.8	52.9
1				3	4.2	48.6
1.2				3	4.2	44.3
1.4				6	8.5	35.8
1.6				1	1.4	34.3
2				3	4.2	30
2.2				2	2.8	27.2
2.4				2	2.8	24.3
2.8				2	2.8	21.5
3.2				2	2.8	18.8
3.8				2	2.8	15.8
4.2				3	4.2	11.5
4.4				3	4.2	7.2
5.4				2	2.8	4.3
5.8				1	1.4	2.8
6.6				1	1.4	1.5
8.8				1	1.4	0
Maximum					8.8	

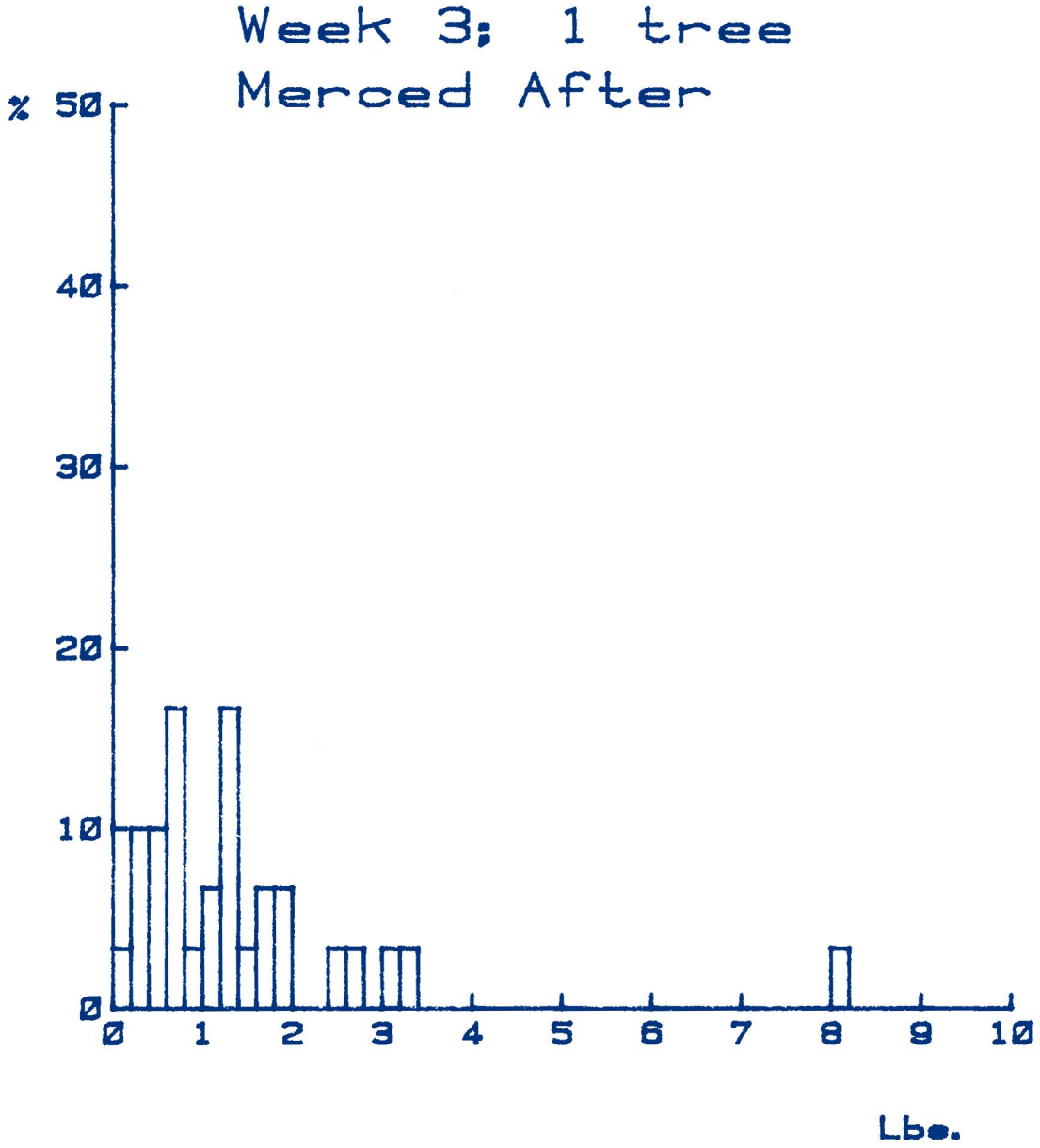
Figure 8 . Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Nonpareil almonds on 09/11/84.



	Before	After
Number	1800	244
Mean	.4208	1.5704
Variance	.1041	2.4248

Lbs.	Num	%	Cum	Num	%	Cum
.2	585	35.3	64.7	10	4	85.9
.4	534	33.3	31.4	28	11.6	84.1
.6	243	15.1	16.2	28	11.4	72.6
.8	121	7.5	8.8	28	11.4	61.1
1	52	3.2	5.4	18	7.7	53.3
1.2	41	2.5	2.8	23	9.4	43.8
1.4	17	1	1.7	20	8.1	35.7
1.6	17	1	.7	21	8.6	27.1
1.8	4	.2	.4	7	2.8	24.2
2	1	0	.4	8	3.2	20.9
2.2	2	.1	.2	7	2.8	18.1
2.4	1	0	.2	5	2	16
2.6	1	0	.1	5	2	14
2.8	0	0	.1	3	1.2	12.7
3.2	0	0	.1	4	1.6	11.1
3.4	1	0	0	4	1.6	9.5
3.6	0	0	0	2	.8	8.6
4	0	0	0	2	.8	7.8
4.2	0	0	0	2	.8	7
4.4	0	0	0	3	1.2	5.6
4.6	0	0	0	1	.4	5.4
4.8	0	0	0	4	1.6	3.7
5.2	0	0	0	1	.4	3.3
6.2	0	0	0	1	.4	2.9
6.4	0	0	0	1	.4	2.5
6.6	0	0	0	1	.4	2.1
7.4	0	0	0	2	.8	1.3
7.6	0	0	0	1	.4	.9
8.2	0	0	0	1	.4	.4
10	0	0	0	1	.4	0
Maximum		3.4			11.1	

Figure 7 . Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Merced almonds on 09/12/84.

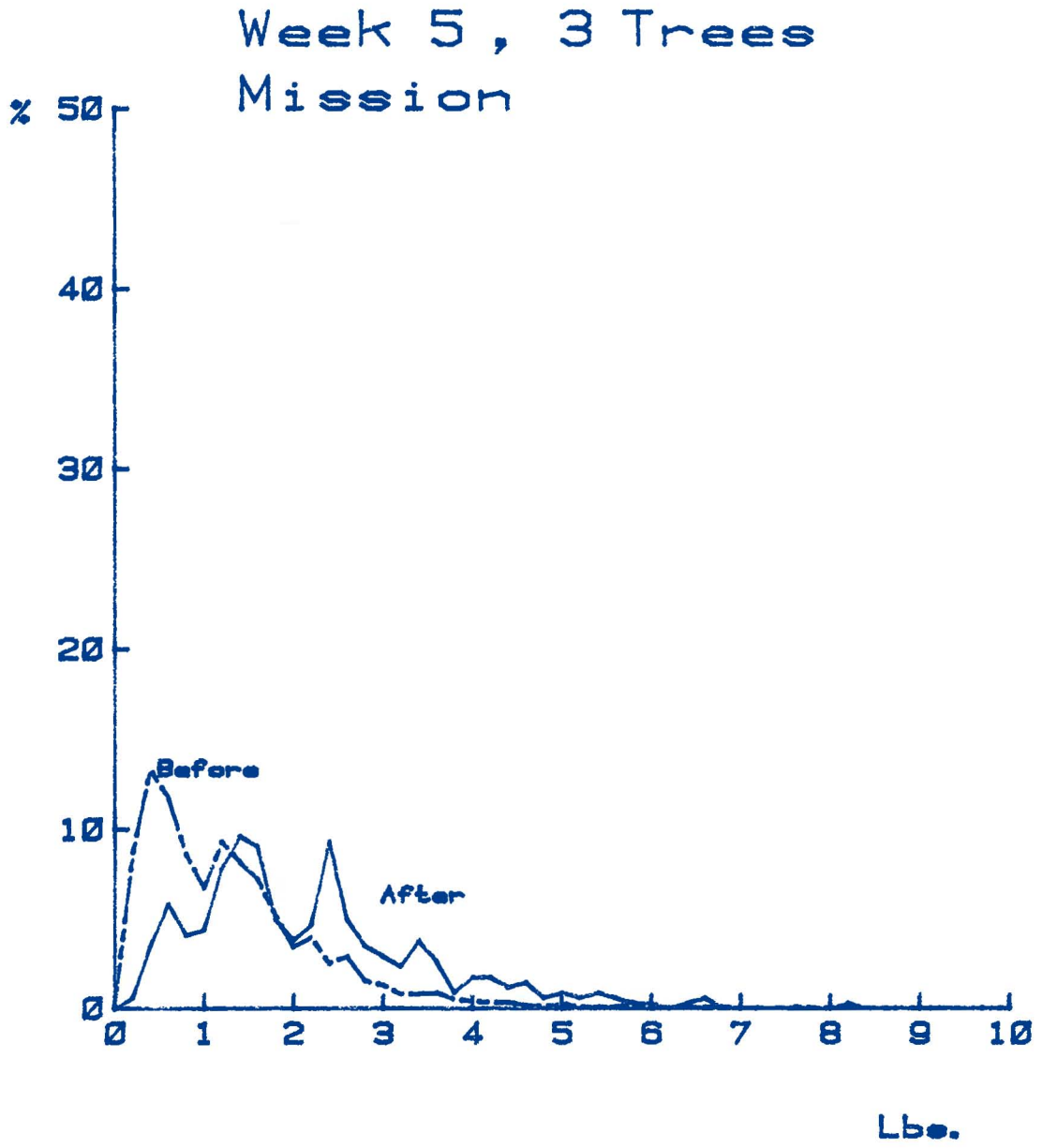


All Types

	After
Number	30
Mean	1.5166
Variance	4.7002

Lbs.	Num	%	Cum	Num	%	Cum
.2				1	3.3	96.7
.4				3	10	86.7
.6				3	10	76.7
.8				5	16.6	60
1				1	3.3	56.7
1.2				2	6.6	50
1.4				5	16.6	33.4
1.6				1	3.3	30
1.8				2	6.6	23.4
2				2	6.6	16.7
2.6				1	3.3	13.4
2.8				1	3.3	10
3.2				1	3.3	6.7
3.4				1	3.3	3.4
8.2				1	3.3	0
Maximum					8.1	

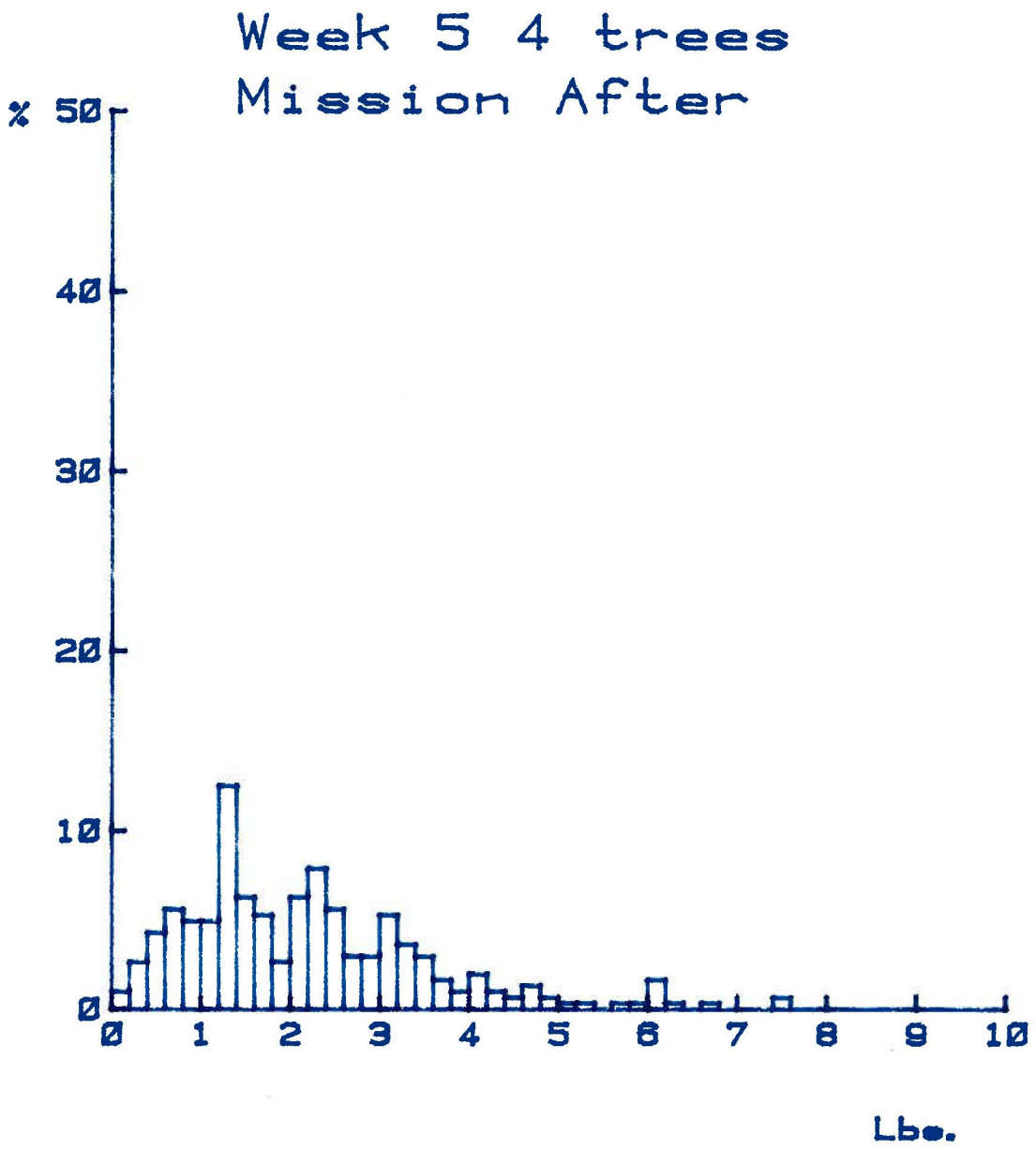
Figure 8 . Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Merced almonds on 09/13/84.



	Before	After
Number	1234	343
Mean	1.2745	2.1586
Variance	1.0388	1.7494

Lbs.	Num	%	Cum	Num	%	Cum
.2	107	8.8	91.4	2	.5	99.5
.4	164	13.2	78.1	12	3.4	98
.6	145	11.7	66.3	20	5.6	90.1
.8	108	8.5	57.7	14	4	86
1	83	6.7	51	15	4.3	81.7
1.2	115	9.3	41.7	27	7.6	73.6
1.4	101	8.1	33.5	33	9.6	64.2
1.6	88	7.2	26.3	31	9	55.1
1.8	64	5.1	21.1	17	4.9	50.2
2	42	3.4	17.7	13	3.7	46.4
2.2	48	3.8	13.7	16	4.6	41.7
2.4	31	2.5	11.2	32	9.3	32.4
2.6	36	2.9	8.3	17	4.9	27.4
2.8	19	1.5	6.8	12	3.4	23.5
3	16	1.2	5.5	10	2.9	21
3.2	10	.8	4.7	8	2.3	18.7
3.4	10	.8	3.8	13	3.7	14.9
3.6	11	.9	3	9	2.6	12.3
3.8	6	.4	2.5	3	.9	11.4
4	5	.4	2.1	6	1.7	8.7
4.2	4	.3	1.7	6	1.7	7.9
4.4	4	.3	1.4	4	1.1	6.7
4.6	2	.1	1.3	5	1.4	5.3
4.8	1	0	1.2	2	.5	4.7
5	3	.2	.8	3	.9	3.8
5-6	6	.4	.4	9	2.6	1.2
6-7	3	.2	.2	3	.9	.3
7-8	1	0	.1	0	0	.3
8-9	1	0	0	1	.2	0
Maximum		8.2			8.2	

Figure 9 . Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Mission almonds on 09/25/84.

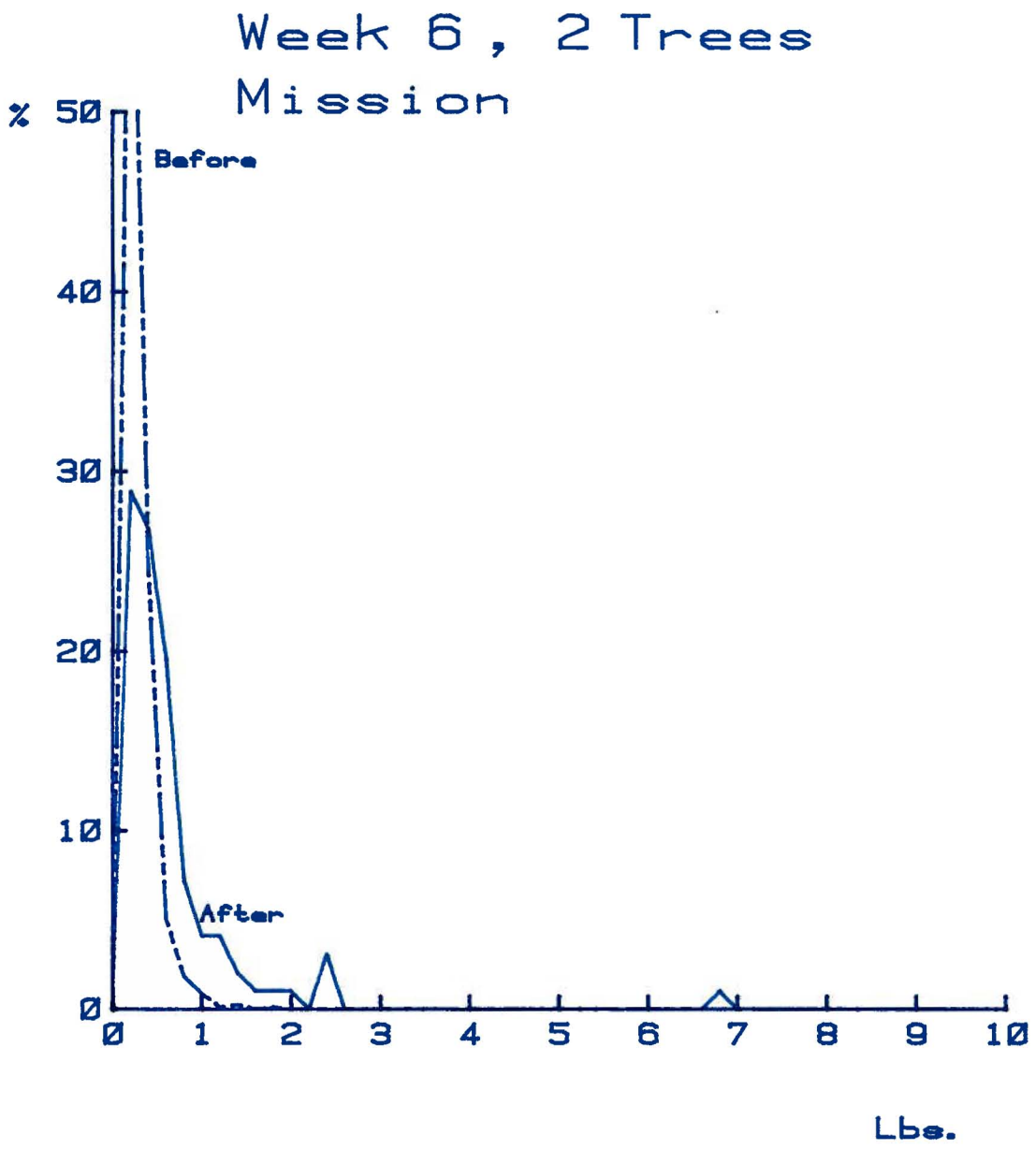


All Types

	After
Number	304
Mean	2.2427
Variance	7.1372

Lbs.	Num	%	Cum	Num	%	Cum
.2				3	.9	99.1
.4				8	2.6	98.4
.6				13	4.2	92.1
.8				17	5.5	88.6
1				15	4.9	81.6
1.2				15	4.9	76.7
1.4				38	12.5	64.2
1.6				19	6.2	57.9
1.8				16	5.2	52.7
2				8	2.6	50
2.2				19	6.2	43.8
2.4				24	7.8	35.9
2.6				17	5.5	30.3
2.8				9	2.9	27.3
3				9	2.9	24.4
3.2				16	5.2	18.1
3.4				11	3.6	15.5
3.6				9	2.9	12.5
3.8				5	1.6	10.9
4				3	.9	9.9
4.2				6	1.9	7.9
4.4				3	.9	6.9
4.6				2	.6	6.3
4.8				4	1.3	5
5				2	.6	4.3
5-6				4	1.3	3
6-7				7	2.3	.7
7-8				2	.6	0
Maximum					7.8	

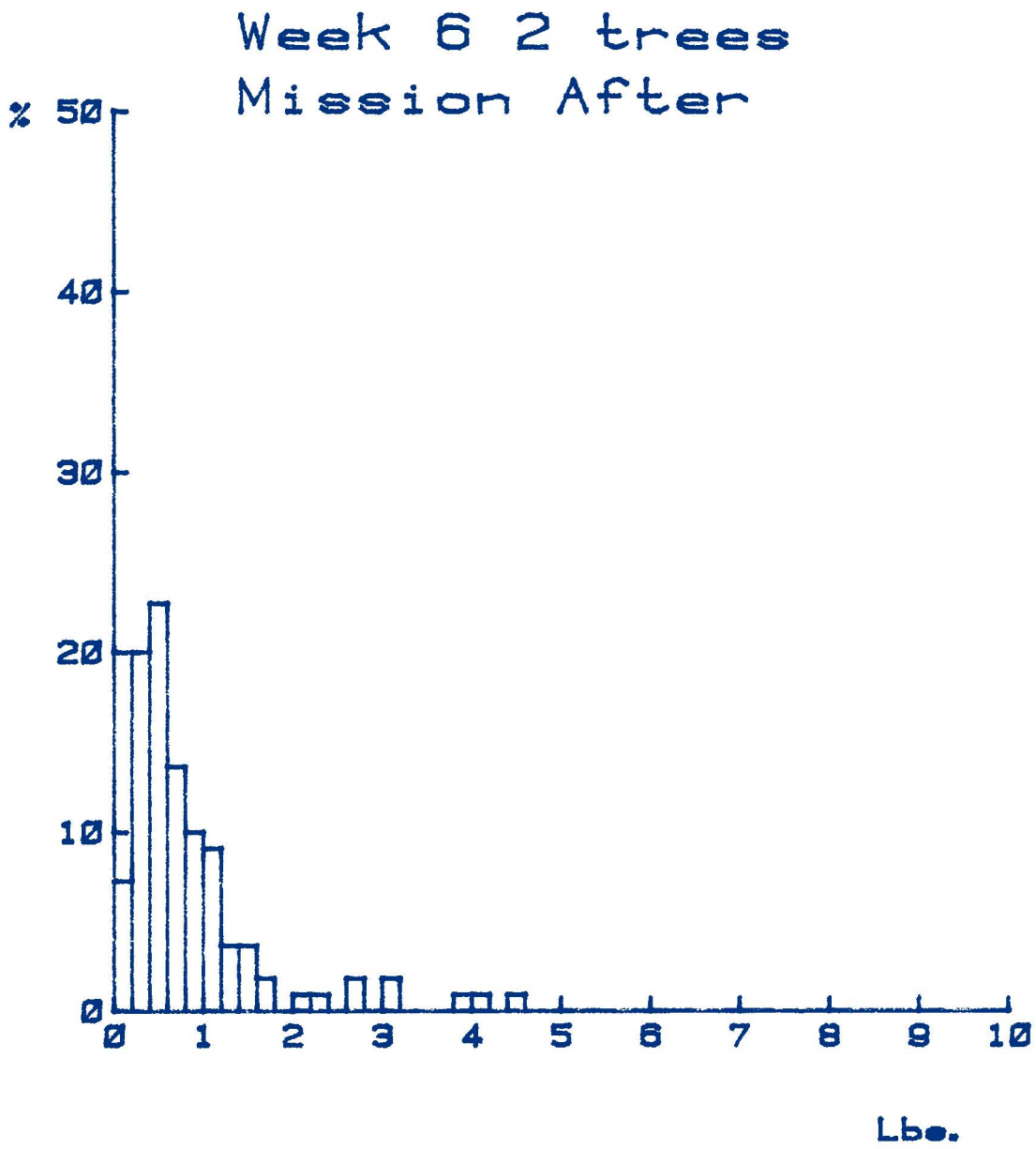
Figure 10. Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Mission almonds on 09/26/84.



	Before	After
Number	811	97
Mean	.2429	.6
Variance	.0294	.6285

Lbs.	Num	%	Cum	Num	%	Cum
.2	547	67.4	32.6	28	28.8	71.2
.4	197	24.2	8.3	26	26.8	44.4
.6	41	5	3.2	19	19.5	24.8
.8	15	1.8	1.4	7	7.2	17.6
1	7	.8	.5	4	4.1	13.4
1.2	1	.1	.4	4	4.1	9.3
1.4	2	.2	.2	2	2	7.3
1.6	0	0	.2	1	1	6.2
1.8	1	.1	0	1	1	5.2
2	0	0	0	1	1	4.2
2.4	0	0	0	3	3	1.1
6.8	0	0	0	1	1	0
Maximum		1.7			6.7	

Figure 11. Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Mission almonds on 10/02/84.

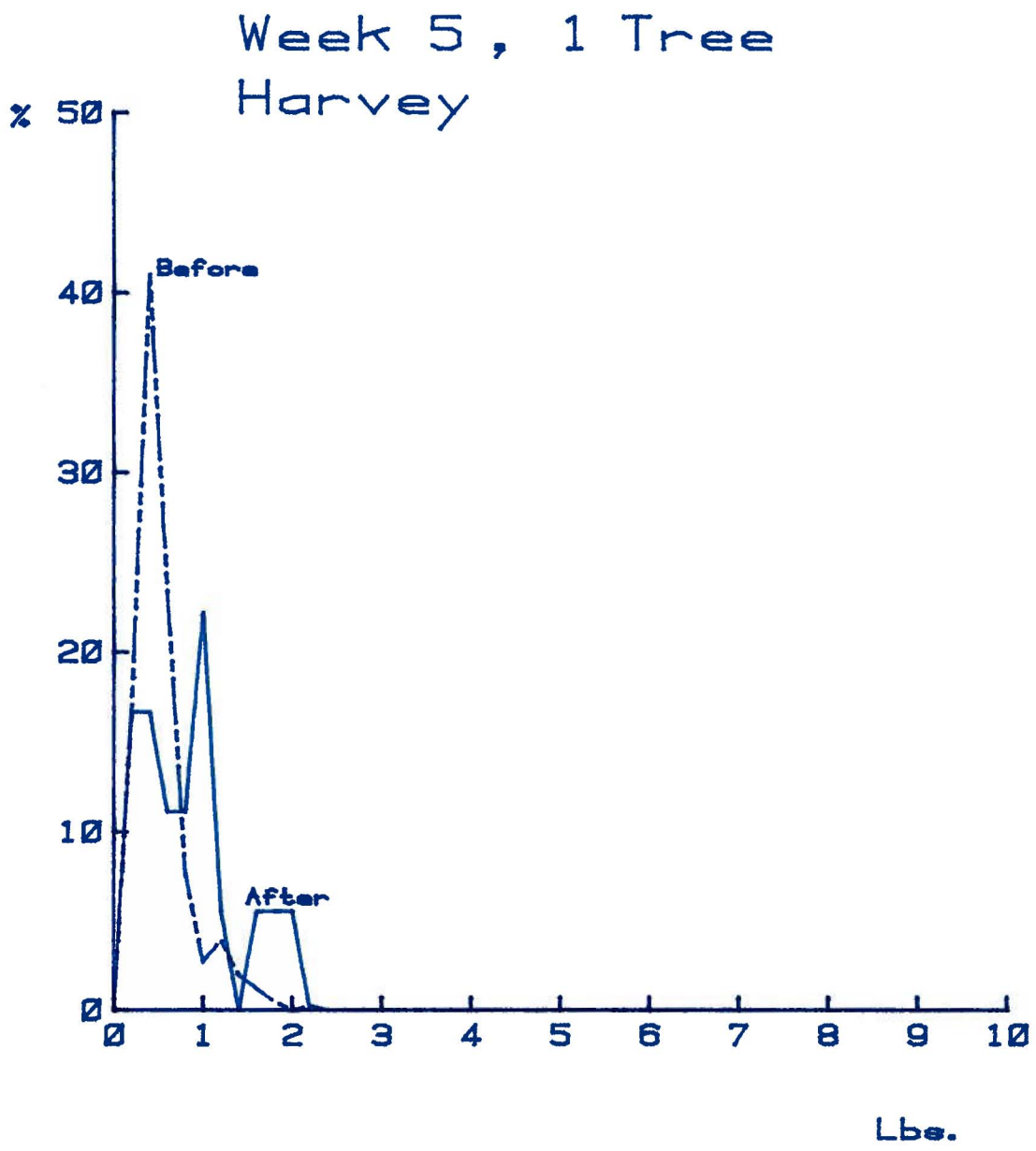


All Types

	After
Number	110
Mean	.9145
Variance	1.5489

Lbs.	Num	%	Cum	Num	%	Cum
.2				8	7.2	92.8
.4				22	20	72.8
.6				25	22.7	50
.8				15	13.6	36.4
1				11	10	26.4
1.2				10	9	17.3
1.4				4	3.6	13.7
1.6				4	3.6	10
1.8				2	1.8	8.2
2.2				1	.9	7.3
2.4				1	.9	6.4
2.8				2	1.8	4.6
3.2				2	1.8	2.8
4				1	.9	1.9
4.2				1	.9	.9
4.6				1	.9	0
Maximum					4.6	

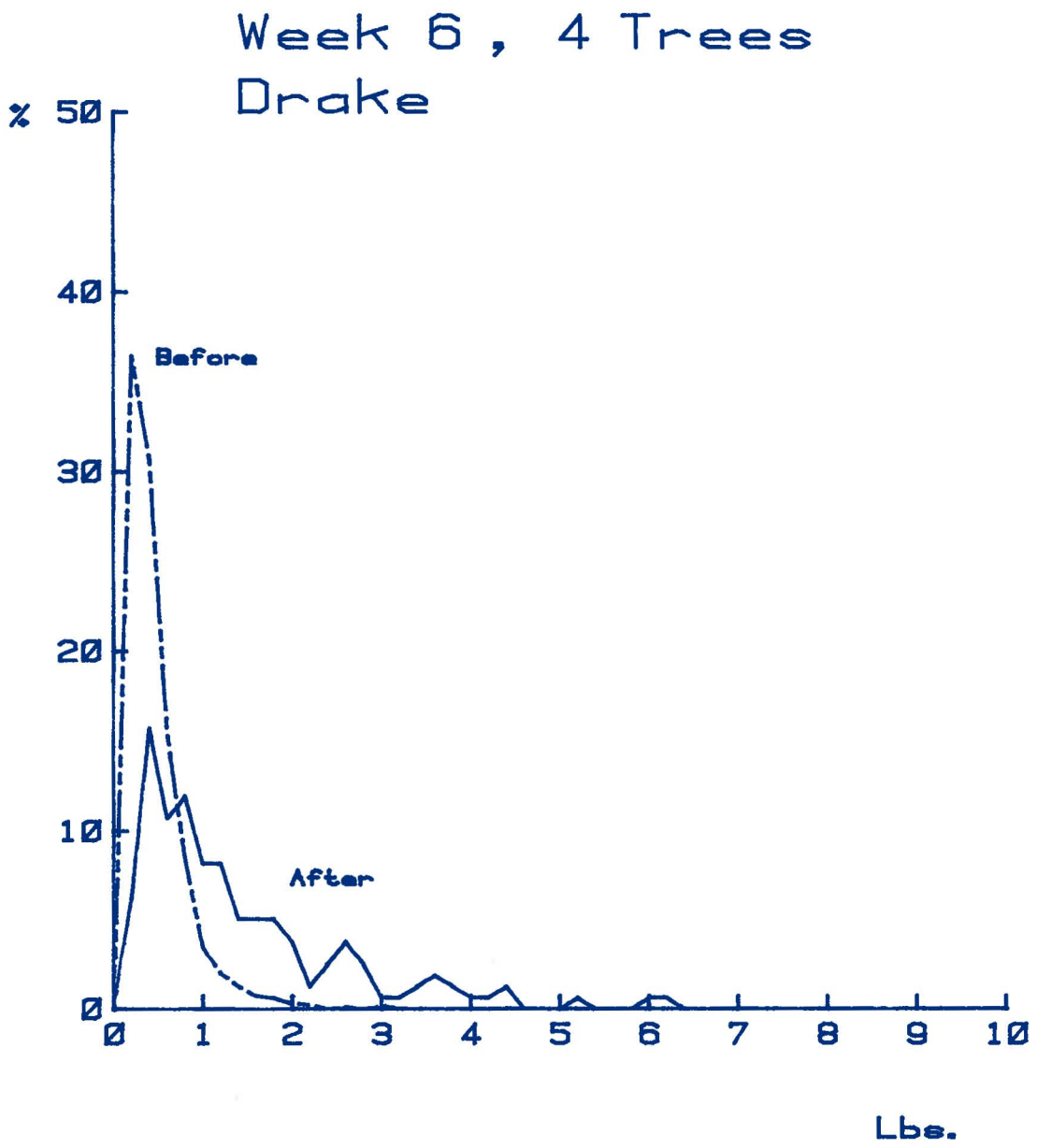
Figure 12. Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Mission almonds on 10/03/84.



	Before	After
Number	405	18
Mean	.4972	.7833
Variance	.0975	.2791

Lbs.	Num	%	Cum	Num	%	Cum
.2	70	17.2	82.8	3	16.6	83.4
.4	166	40.9	41.8	3	16.6	66.7
.6	95	23.4	18.3	2	11.1	55.6
.8	31	7.6	10.7	2	11.1	44.5
1	11	2.7	7.9	4	22.2	22.3
1.2	18	3.9	4	1	5.5	16.7
1.4	8	1.9	2	0	0	16.7
1.6	5	1.2	.8	1	5.5	11.2
1.8	2	.4	.3	1	5.5	5.8
2	0	0	.3	1	5.5	0
2.2	1	.2	0	0	0	0
Maximum		2.1			1.9	

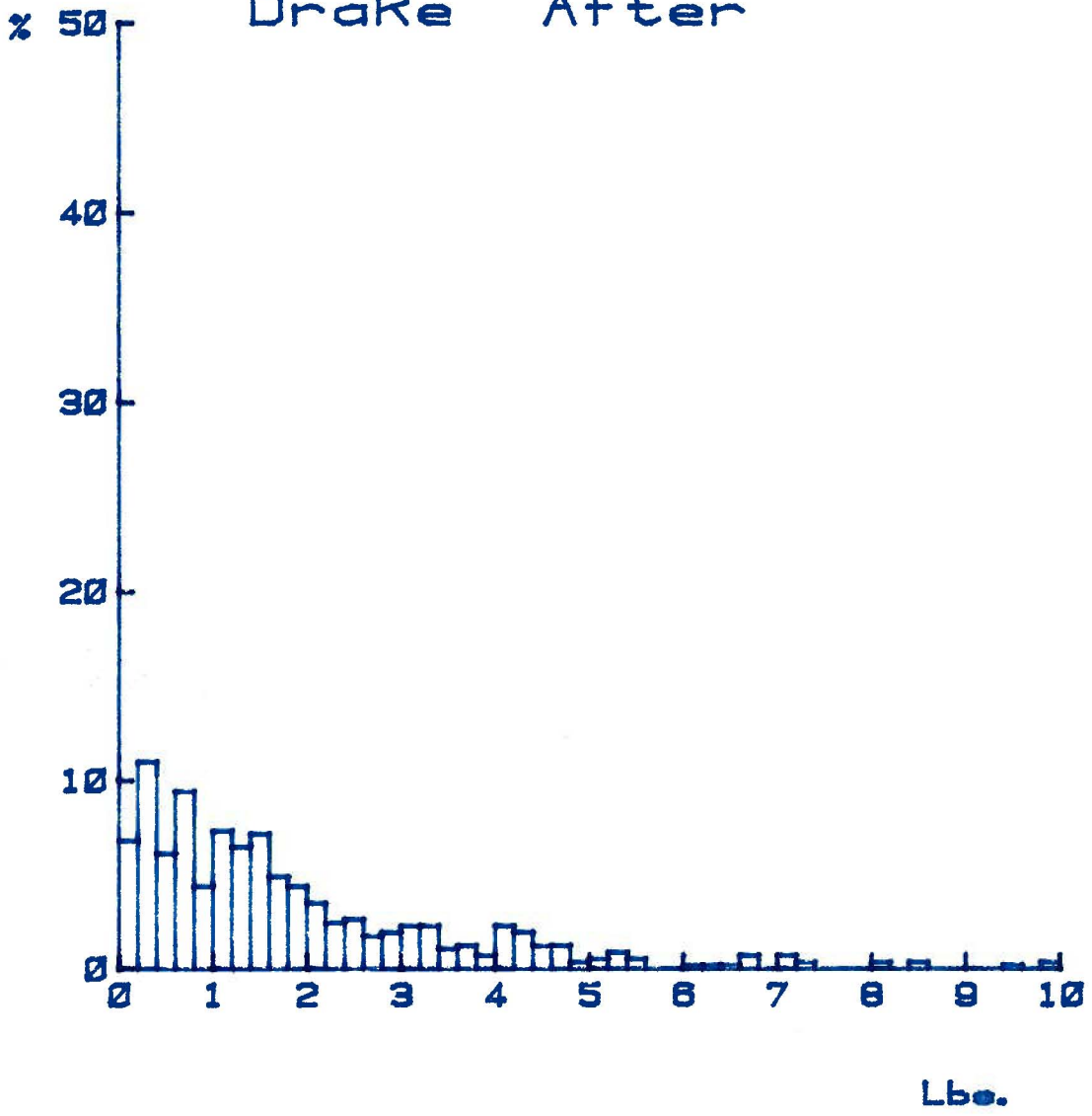
Figure 13. Frequency table and histogram for all nut detachment forces in lbs. measured for Harvey almonds during 1984.



	Before	After
Number	1675	159
Mean	.428	1.349
Variance	.1401	1.3597

Lbs.	Num	%	Cum	Num	%	Cum
.2	810	38.4	83.6	10	6.2	93.8
.4	514	30.6	32.9	25	15.7	78
.6	280	15.5	17.4	17	10.6	67.3
.8	141	8.4	9	19	11.9	55.4
1	58	3.4	5.5	13	8.1	47.2
1.2	33	1.9	3.6	13	8.1	39
1.4	21	1.2	2.3	8	5	34
1.6	12	.7	1.6	8	5	29
1.8	10	.5	1	8	5	23.9
2	5	.2	.7	6	3.7	20.2
2.2	4	.2	.5	2	1.2	16.9
2.4	0	0	.5	4	2.5	16.4
2.6	2	.1	.3	6	3.7	12.6
2.8	0	0	.3	4	2.5	10.1
3	3	.1	.2	1	.6	9.5
3.2	0	0	.2	1	.6	8.8
3.4	0	0	.2	2	1.2	7.6
3.6	0	0	.2	3	1.8	5.7
3.8	0	0	.2	2	1.2	4.4
4	0	0	.2	1	.6	3.8
4.2	0	0	.2	1	.6	3.2
4.4	1	0	.1	2	1.2	1.9
4.6	1	0	0	0	0	1.9
5.2	0	0	0	1	.6	1.3
8	0	0	0	1	.6	.7
8.2	0	0	0	1	.6	0
Maximum		4.5			8.1	

Figure 14. Frequency table and histogram for nut detachment forces in lbs. measured before and after harvest for Drake almonds on 10/04/84.

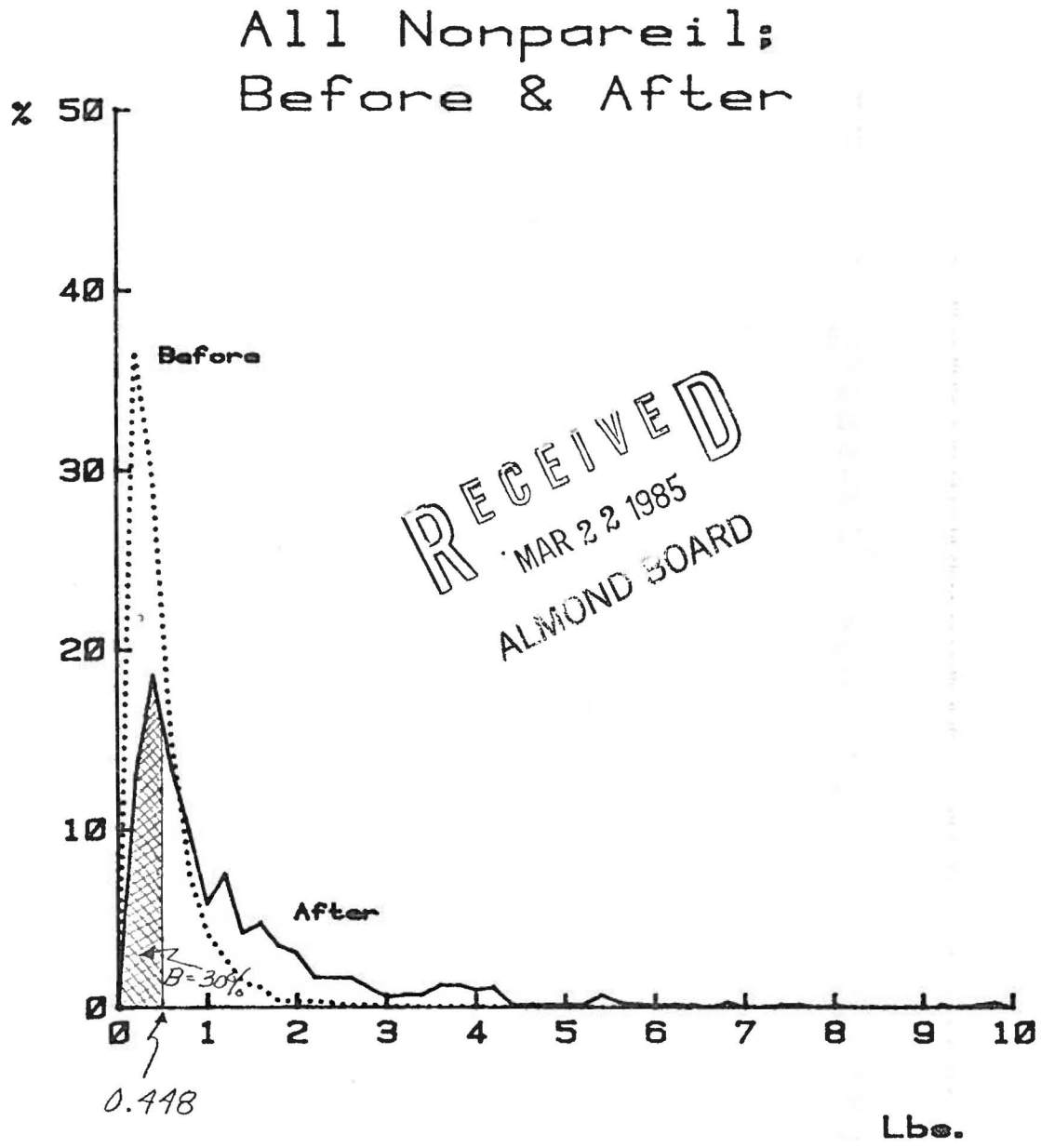


All Types

	After
Number	573
Mean	1.9012
Variance	7.2023

Lbs.	Num	%	Cum	Num	%	Cum
.2				38	6.6	93.2
.4				63	10.9	82.2
.6				35	6.1	76.1
.8				54	9.4	68.7
1				25	4.3	62.3
1.2				42	7.3	55
1.4				37	6.4	48.6
1.6				41	7.1	41.4
1.8				28	4.8	36.5
2				25	4.3	32.2
2.2				20	3.4	28.7
2.4				14	2.4	26.2
2.6				15	2.6	23.6
2.8				10	1.7	21.9
3				11	1.9	19.9
3.2				13	2.2	17.7
3.4				13	2.2	15.4
3.6				6	1	14.4
3.8				7	1.2	13.1
4				4	.6	12.4
4.2				13	2.2	10.2
4.4				11	1.9	8.2
4.6				7	1.2	7
4.6				7	1.2	5.8
5				2	.3	5.5
5-6				11	1.9	3.5
6-7				7	1.2	2.3
7-8				6	1	1.3
8-9				4	.6	.6
9-10				3	.5	0
Maximum					11.3	

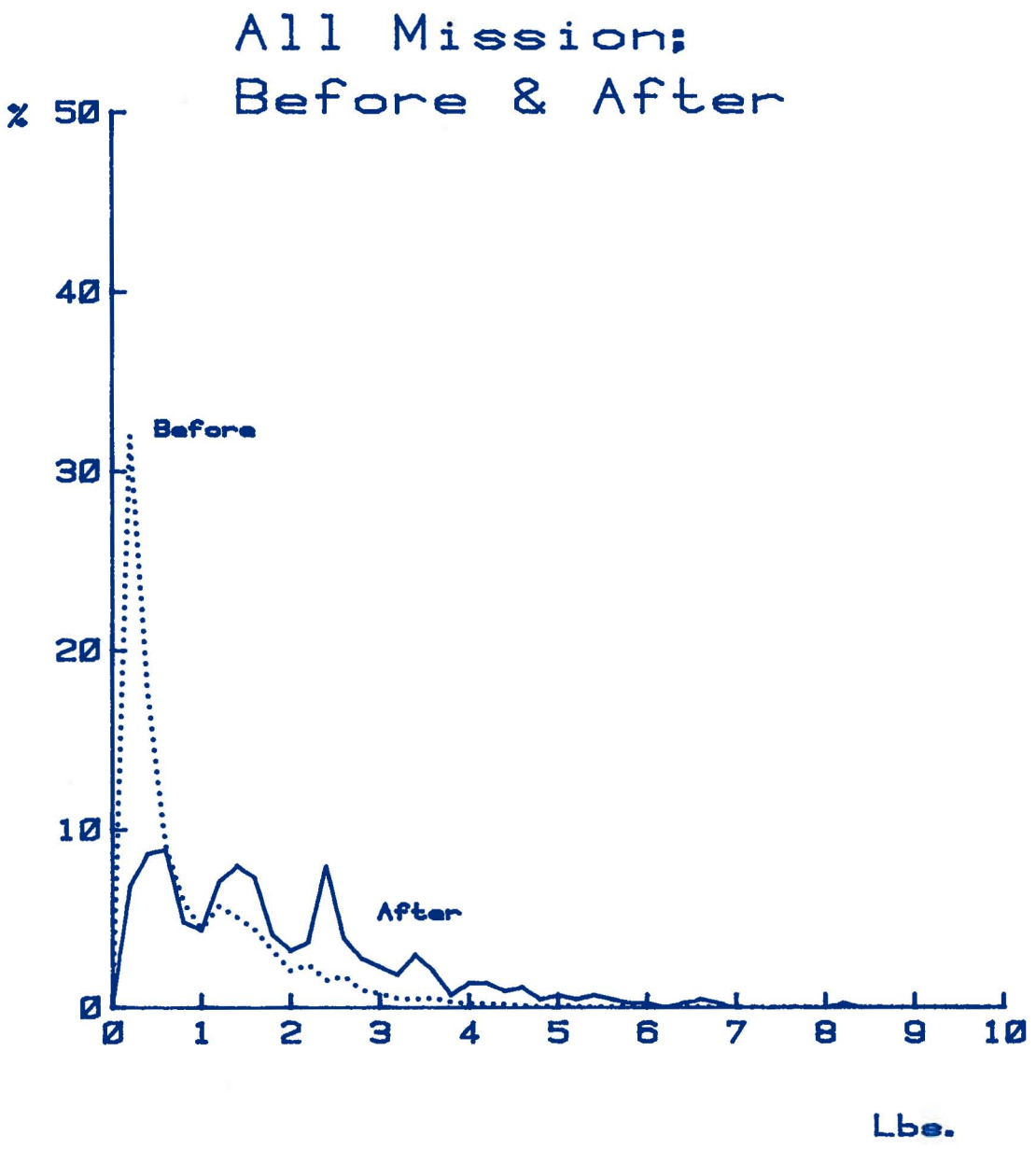
Figure 15. Frequency table and histogram for nut detachment forces in lbs. measured only after harvest for Drake almonds on 10/06/84.



	Before	After
Number	4937	722
Mean	.4483	1.2843
Variance	.1892	2.3398

Lbs.	Num	%	Cum	Num	%	Cum
.2	1808	36.6	63.4	94	13	87
.4	1460	29.5	33.8	134	18.5	68.5
.6	750	15.1	18.7	97	13.4	55
.8	371	7.5	11.1	71	9.8	45.2
1	204	4.1	7	42	5.8	39.4
1.2	136	2.7	4.3	54	7.4	31.9
1.4	88	1.9	2.9	30	4.1	27.7
1.6	54	1	1.8	34	4.7	29
1.8	17	.3	1.4	25	3.4	19.8
2	18	.3	1.1	22	3	18.5
2.2	15	.3	.8	12	1.6	14.9
2.4	12	.2	.6	12	1.6	13.2
2.6	5	.1	.5	12	1.6	11.5
2.8	8	.1	.3	8	1.1	10.4
3	1	0	.3	4	.5	9.9
3.2	4	0	.2	5	.6	9.2
3.4	0	0	.2	5	.6	8.5
3.6	2	0	.2	9	1.2	7.2
3.8	3	0	.1	9	1.2	6
4	1	0	.1	7	.9	5
4.2	1	0	.1	8	1.1	3.9
4.4	0	0	.1	1	.1	3.8
4.6	0	0	.1	1	.1	3.6
4.8	0	0	.1	1	.1	3.5
5	0	0	.1	1	.1	3.4
5-6	0	0	.1	10	1.3	2
6-7	0	0	.1	4	.5	1.4
7-8	1	0	0	3	.4	1
8-10	0	0	0	7	.9	0
Maximum		8			12.2	

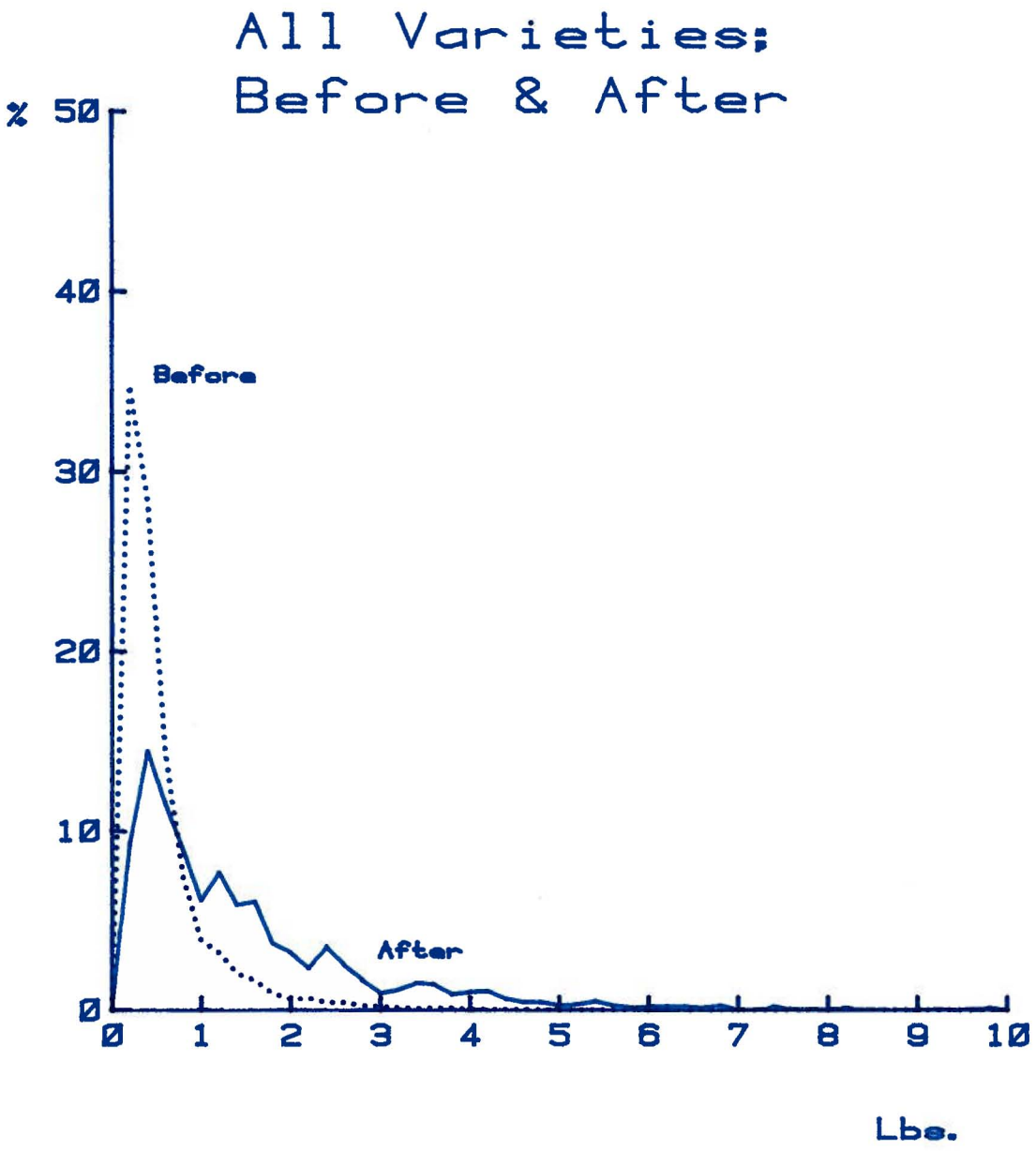
Figure 16. Frequency table and histogram for all nut detachment forces in lbs. measured both before and after harvest for Nonpareil almonds during 1984.



	Before	After
Number	2045	440
Mean	.8654	1.815
Variance	.8937	1.9187

Lbs.	Num	%	Cum	Num	%	Cum
.2	654	31.9	68.1	30	6.8	93.2
.4	361	17.6	50.4	38	8.6	84.6
.6	186	9	41.3	39	8.8	75.7
.8	121	5.9	35.4	21	4.7	70.9
1	90	4.4	31	19	4.3	66.6
1.2	116	5.6	25.3	31	7	59.6
1.4	103	5	20.3	35	7.9	51.6
1.6	89	4.3	15.9	32	7.2	44.4
1.8	65	3.1	12.8	18	4	40.3
2	42	2	10.7	14	3.1	37.1
2.2	49	2.3	8.3	16	3.6	33.4
2.4	31	1.5	6.8	35	7.9	25.5
2.6	36	1.7	5	17	3.8	21.6
2.8	19	.9	4.1	12	2.7	18.9
3	16	.7	3.3	10	2.2	16.6
3.2	10	.4	2.8	6	1.8	14.8
3.4	10	.4	2.3	13	2.9	11.9
3.6	11	.5	1.8	9	2	9.8
3.8	6	.2	1.5	3	.6	9.1
4	5	.2	1.3	6	1.3	7.8
4.2	4	.1	1.1	6	1.3	6.4
4.4	4	.1	.9	4	.9	5.5
4.6	2	0	.8	5	1.1	4.4
4.8	1	0	.7	2	.4	3.9
5	3	.1	.6	3	.6	3.2
5-6	6	.2	.3	9	2	1.2
6-7	3	.1	.1	4	.9	.3
7-8	1	0	.1	0	0	.3
8-9	1	0	0	1	.2	0
Maximum		8.2			8.2	

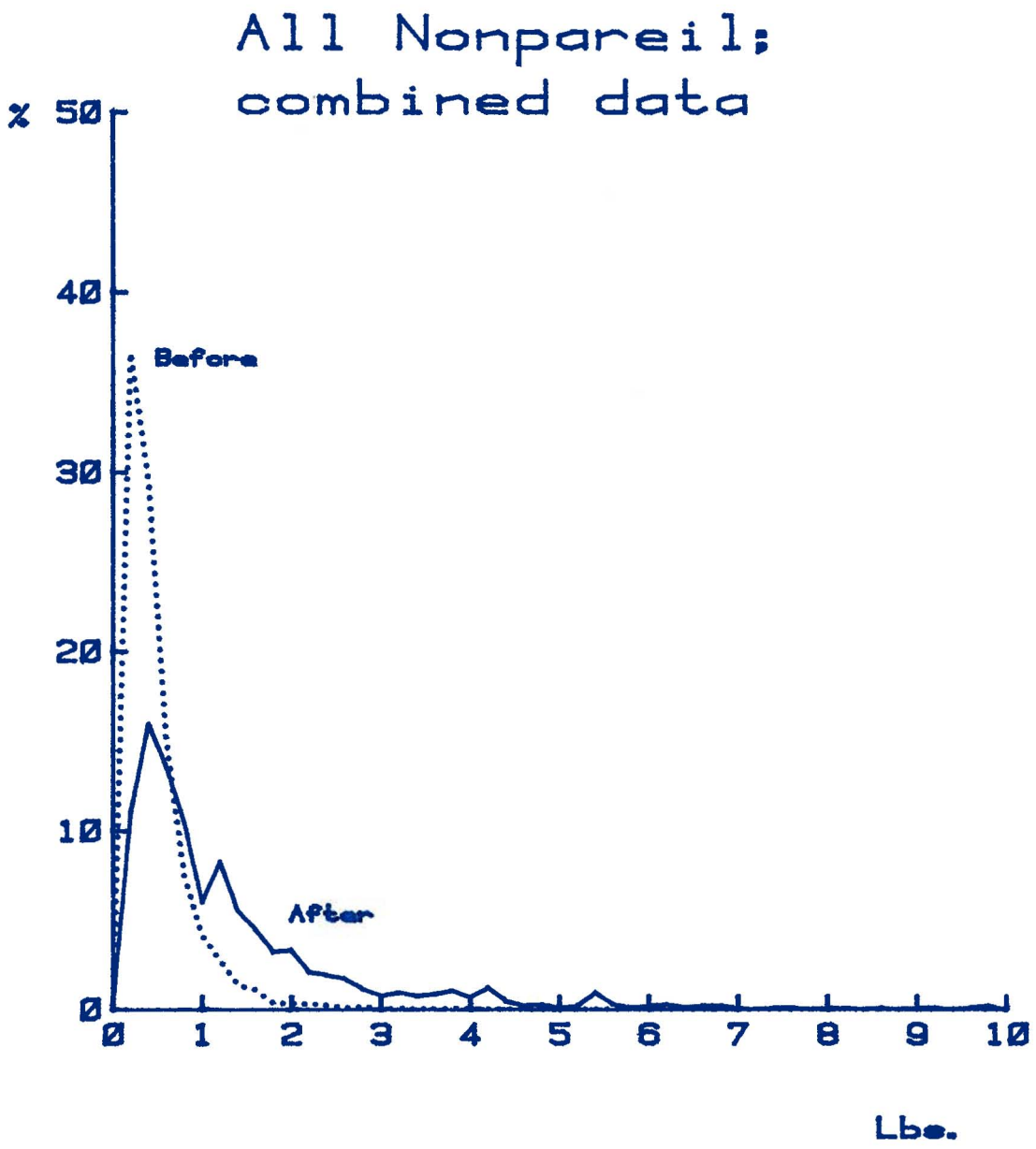
Figure 17. Frequency table and histogram for all nut detachment forces in lbs. measured both before and after harvest for Mission almonds during 1984.



	Before	After
Number	10662	1583
Mean	.5228	1.4787
Variance	.3191	2.1672

Lbs.	Num	%	Cum	Num	%	Cum
.2	3707	34.7	85.3	147	9.2	90.8
.4	3035	28.4	36.8	228	14.4	76.3
.6	1534	14.3	22.4	183	11.5	64.7
.8	785	7.3	15.1	141	8.9	55.8
1	415	3.8	11.2	97	8.1	49.7
1.2	342	3.2	8	122	7.7	42
1.4	217	2	5.8	93	5.8	36.1
1.6	177	1.6	4.3	96	6	30
1.8	98	.9	3.3	59	3.7	26.3
2	84	.8	2.7	51	3.2	23.1
2.2	71	.6	2.1	37	2.3	20.8
2.4	44	.4	1.7	56	3.5	17.2
2.6	44	.4	1.2	40	2.5	14.7
2.8	27	.2	1	27	1.7	13
3	20	.1	.8	15	.9	12
3.2	14	.1	.7	18	1.1	10.9
3.4	11	.1	.6	24	1.5	9.4
3.6	13	.1	.5	23	1.4	7.8
3.8	8	0	.4	14	.8	7.1
4	6	0	.3	18	1	6
4.2	5	0	.3	17	1	5
4.4	5	0	.2	10	.6	4.3
4.6	3	0	.2	7	.4	3.8
4.8	1	0	.2	7	.4	3.5
5	3	0	.2	4	.2	3.2
5-6	6	0	.1	22	1.3	1.8
6-7	3	0	.1	12	.7	1.1
7-8	2	0	0	6	.3	.7
8-9	1	0	0	2	.1	.5
9-10	0	0	0	8	.5	0
Maximum		8.2			12.2	

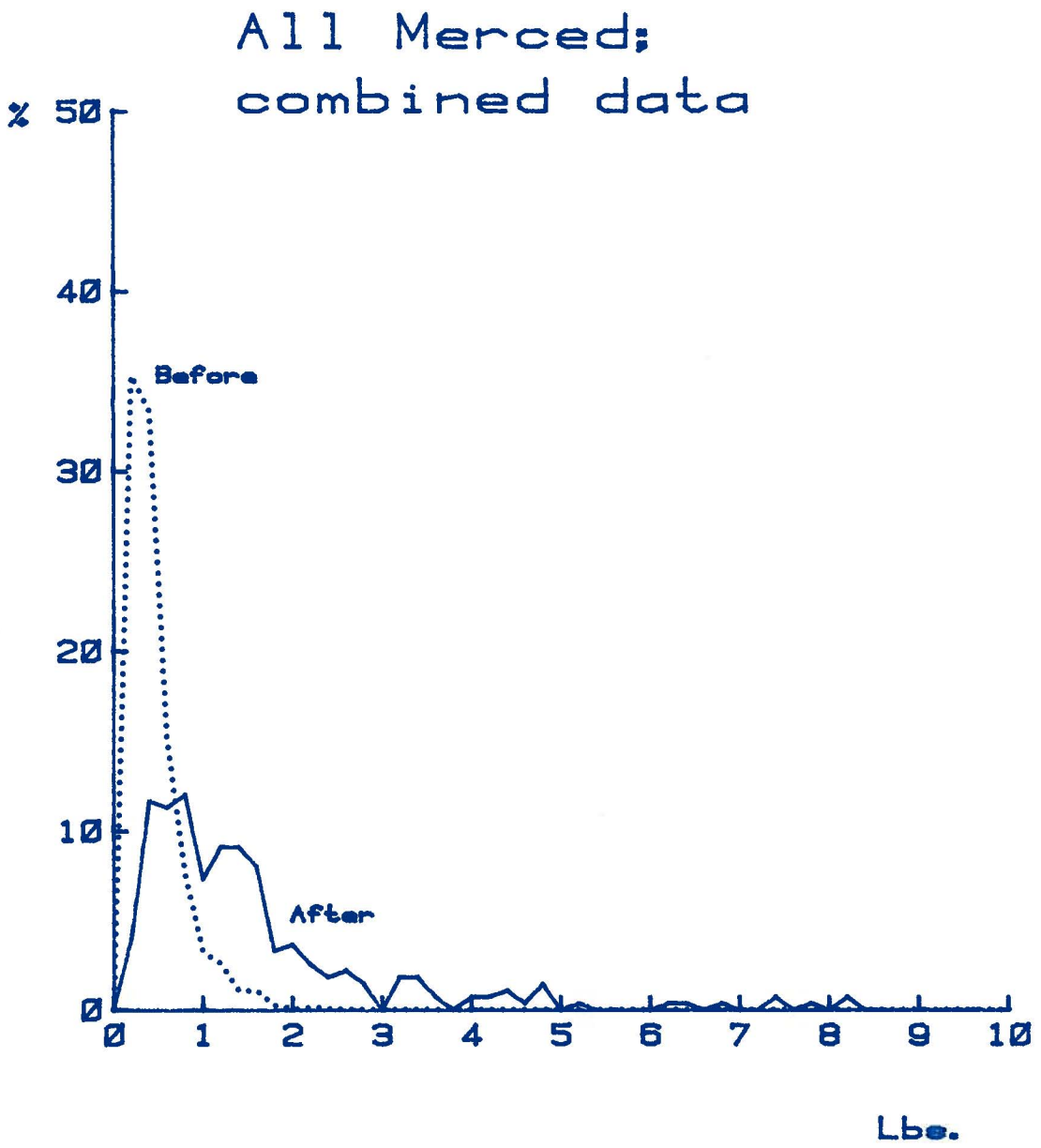
Figure 18. Frequency table and histogram for all nut detachment forces in lbs. measured both before and after harvest for All almonds during 1984.



	Before	After
Number	4937	1050
Mean	.4483	1.3526
Variance	.1892	3.1222

Lbs.	Num	%	Cum	Num	%	Cum
.2	1808	36.6	63.4	116	11	89
.4	1460	29.5	33.8	188	18	73
.6	750	15.1	18.7	143	13.6	59.4
.8	371	7.5	11.1	110	10.4	48.9
1	204	4.1	7	89	8	42.9
1.2	136	2.7	4.9	87	8.2	34.6
1.4	88	1.8	2.9	58	5.5	29.1
1.6	54	1	1.8	47	4.4	24.6
1.8	17	.3	1.4	34	3.2	21.4
2	18	.3	1.1	35	3.3	18
2.2	15	.3	.8	22	2	15.8
2.4	12	.2	.6	20	1.9	14
2.6	5	.1	.5	18	1.7	12.3
2.8	8	.1	.3	12	1.1	11.2
3	1	0	.3	8	.7	10.4
3.2	4	0	.2	10	.9	9.5
3.4	0	0	.2	8	.7	8.7
3.6	2	0	.2	9	.8	7.8
3.8	3	0	.1	11	1	6.8
4	1	0	.1	7	.6	6.1
4.2	1	0	.1	13	1.2	4.9
4.4	0	0	.1	5	.4	4.4
4.6	0	0	.1	2	.1	4.2
4.8	0	0	.1	3	.2	3.8
5	0	0	.1	1	0	3.8
5-6	0	0	.1	18	1.7	2.1
6-7	0	0	.1	8	.8	1.3
7-8	1	0	0	3	.2	1
8-9	0	0	0	3	.2	.7
9-10	0	0	0	7	.6	0
Maximum		8			12.2	

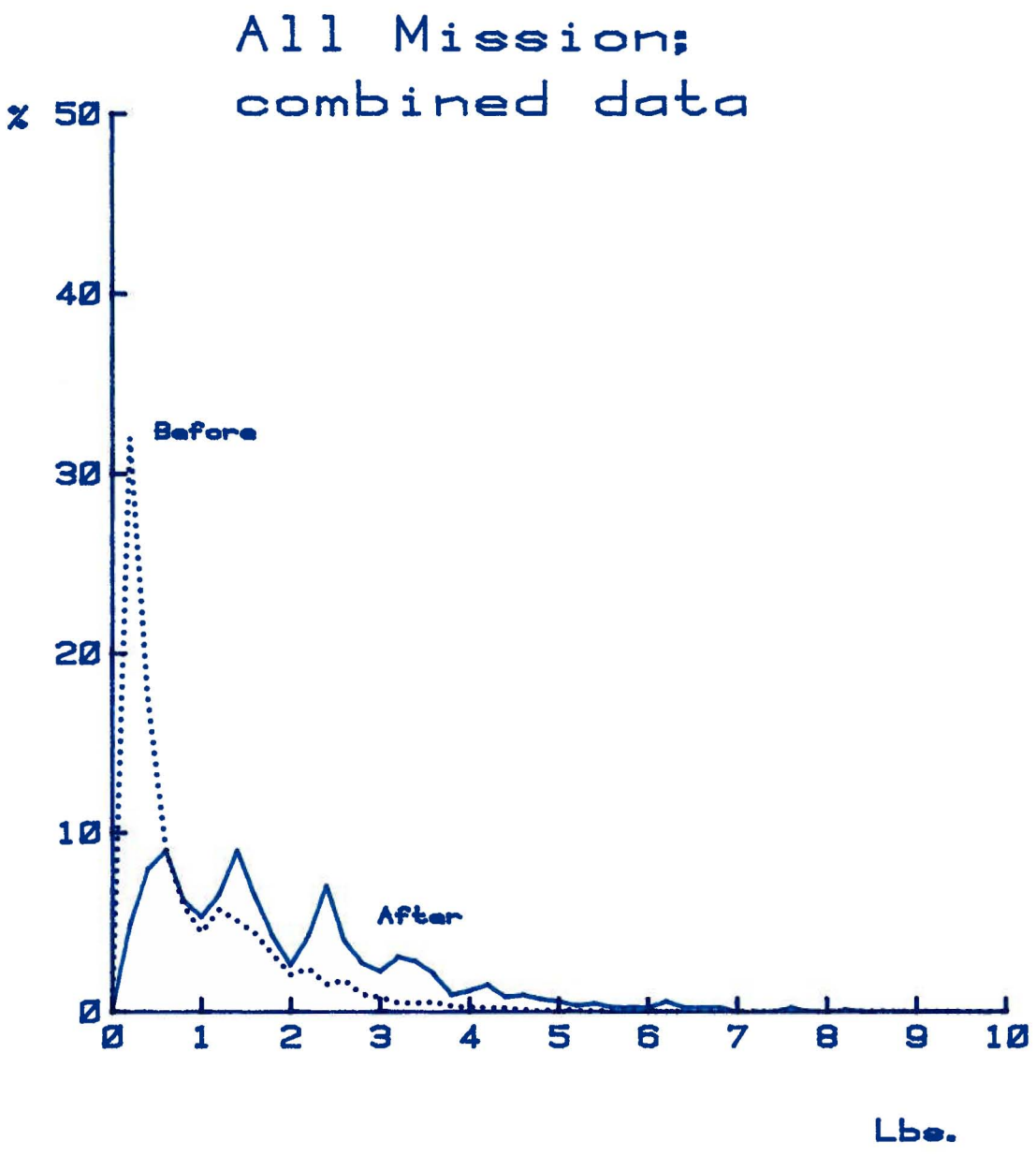
Figure 19. Frequency table and histogram for all nut detachment forces in lbs. measured for Nonpareil almonds during 1984.



	Before	After
Number	1600	274
Mean	.4206	1.5645
Variance	.1041	2.8579

Lbs.	Num	%	Cum	Num	%	Cum
.2	585	35.9	64.7	11	4	96
.4	534	33.3	31.4	32	11.6	84.3
.6	243	15.1	16.2	31	11.3	73
.8	121	7.5	8.6	33	12	61
1	52	3.2	5.4	20	7.2	53.7
1.2	41	2.5	2.8	25	9.1	44.6
1.4	17	1	1.7	25	9.1	35.4
1.6	17	1	.7	22	8	27.4
1.8	4	.2	.4	9	3.2	24.1
2	1	0	.4	10	3.6	20.5
2.2	2	.1	.2	7	2.5	17.9
2.4	1	0	.2	5	1.8	18.1
2.6	1	0	.1	6	2.1	13.9
2.8	0	0	.1	4	1.4	12.4
3.2	0	0	.1	5	1.8	10.6
3.4	1	0	0	5	1.8	8.8
3.6	0	0	0	2	.7	8.1
4	0	0	0	2	.7	7.3
4.2	0	0	0	2	.7	6.6
4.4	0	0	0	3	1	5.5
4.6	0	0	0	1	.3	5.1
4.8	0	0	0	4	1.4	3.7
5.2	0	0	0	1	.3	3.3
6.2	0	0	0	1	.3	3
6.4	0	0	0	1	.3	2.6
6.8	0	0	0	1	.3	2.2
7.4	0	0	0	2	.7	1.5
7.6	0	0	0	1	.3	1.1
8.2	0	0	0	2	.7	.4
10	0	0	0	1	.3	0
Maximum		3.4			11.1	

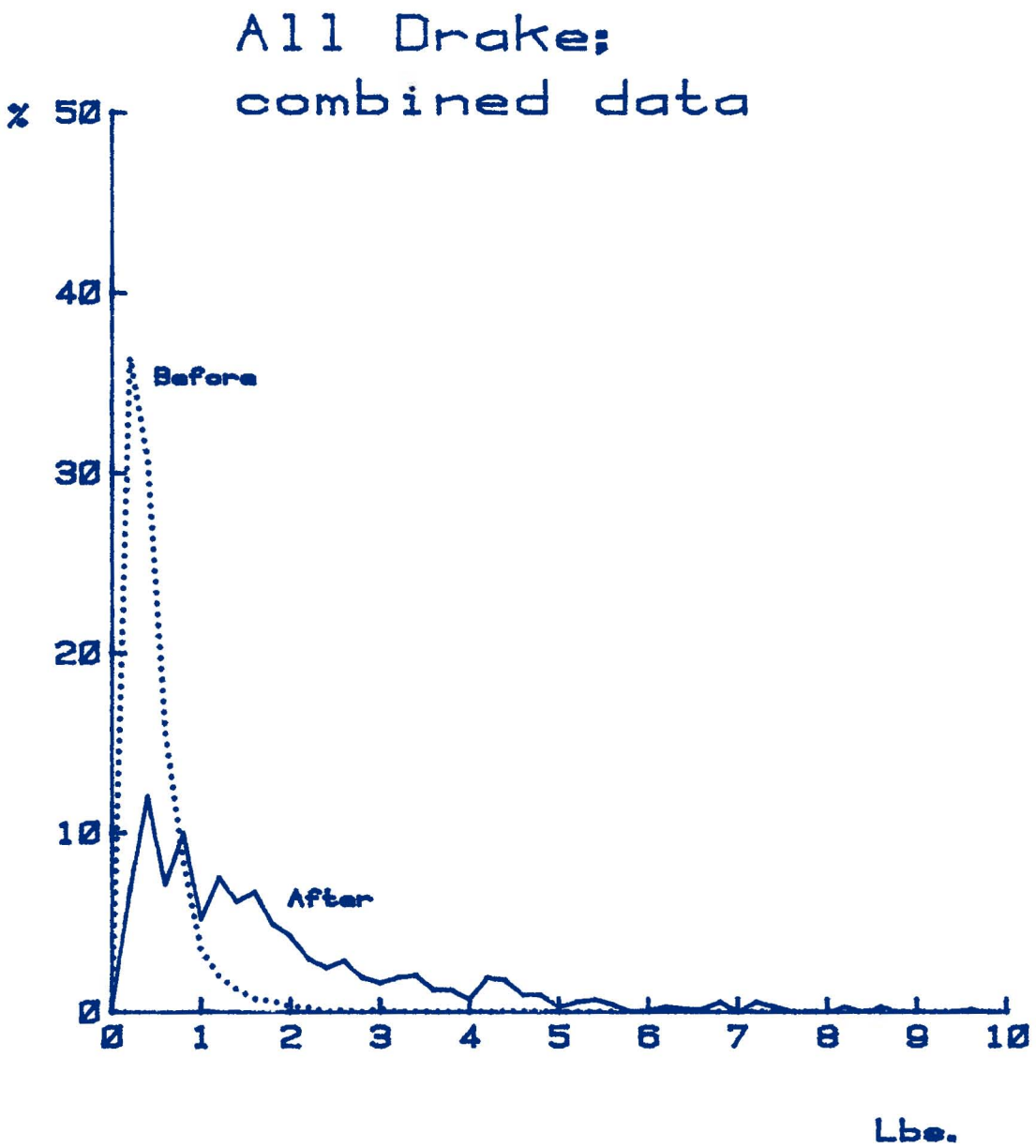
Figure 20. Frequency table and histogram for all nut detachment forces in lbs. measured for Merced almonds during 1984.



	Before	After
Number	2045	854
Mean	.8654	1.8512
Variance	.8937	3.8891

Lbs.	Num	%	Cum	Num	%	Cum
.2	654	31.9	88.1	41	4.8	95.2
.4	361	17.6	50.4	68	7.9	87.3
.6	188	9	41.3	77	9	78.3
.8	121	5.8	35.4	53	6.2	72.1
1	90	4.4	31	45	5.2	66.9
1.2	116	5.6	25.3	56	6.5	60.2
1.4	103	5	20.3	77	9	51.2
1.6	89	4.3	15.9	55	6.4	44.6
1.8	65	3.1	12.8	36	4.2	40.6
2	42	2	10.7	22	2.5	36
2.2	49	2.3	8.3	36	4.2	33.6
2.4	31	1.5	6.8	60	7	28.7
2.6	36	1.7	5	34	3.9	22.6
2.8	19	.9	4.1	23	2.6	20.1
3	16	.7	3.3	19	2.2	17.6
3.2	10	.4	2.6	26	3	14.6
3.4	10	.4	2.3	24	2.6	12
3.6	11	.5	1.6	16	2.1	9.9
3.8	6	.2	1.5	8	.9	6.9
4	5	.2	1.3	10	1.1	7.8
4.2	4	.1	1.1	13	1.5	6.2
4.4	4	.1	.9	7	.8	5.4
4.6	2	0	.8	8	.9	4.5
4.8	1	0	.7	6	.7	3.6
5	3	.1	.6	5	.5	3.2
5-6	6	.2	.3	13	1.5	1.7
6-7	3	.1	.1	11	1.2	.4
7-8	1	0	.1	2	.2	.2
8-9	1	0	0	1	.1	0
Maximum		8.2			8.2	

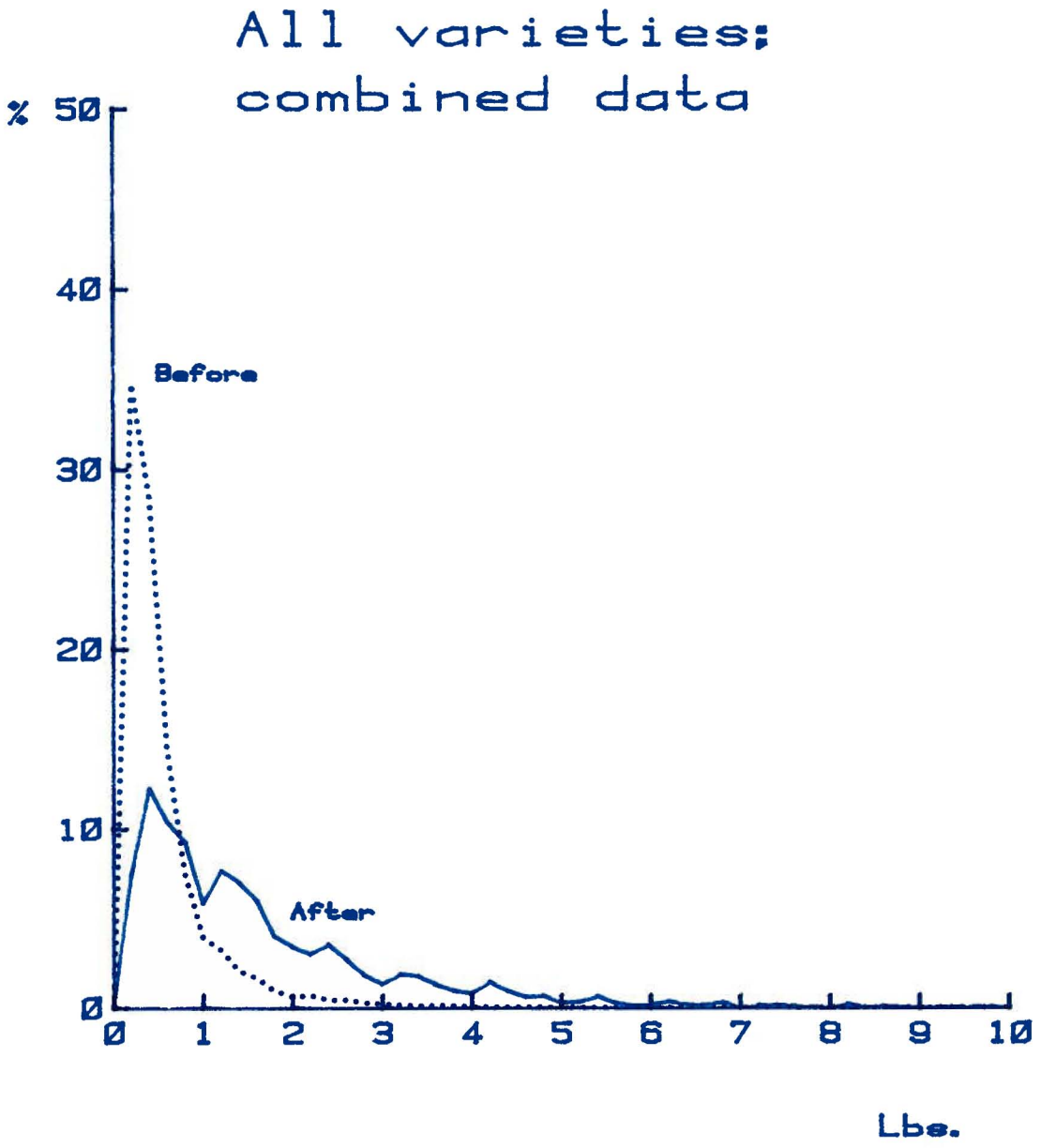
Figure 21. Frequency table and histogram for all nut detachment forces in lbs. measured for Mission almonds during 1984.



	Before	After
Number	1675	732
Mean	.428	1.7812
Variance	.1401	5.9815

Lbs.	Num	%	Cum	Num	%	Cum
.2	610	36.4	63.6	49	6.6	93.3
.4	514	30.6	32.9	88	12	81.3
.6	200	15.5	17.4	52	7.1	74.2
.8	141	8.4	9	73	9.9	64.2
1	58	3.4	5.5	38	5.1	59.1
1.2	39	1.9	3.6	55	7.5	51.5
1.4	21	1.2	2.3	45	6.1	45.4
1.6	12	.7	1.6	48	6.6	38.7
1.8	10	.5	1	36	4.9	33.8
2	5	.2	.7	31	4.2	28.5
2.2	4	.2	.5	22	3	26.5
2.4	0	0	.5	18	2.4	24.1
2.6	2	.1	.3	21	2.8	21.2
2.8	0	0	.3	14	1.9	18.3
3	3	.1	.2	12	1.6	17.7
3.2	0	0	.2	14	1.9	15.8
3.4	0	0	.2	15	2	13.7
3.6	0	0	.2	9	1.2	12.5
3.8	0	0	.2	9	1.2	11.2
4	0	0	.2	5	.6	10.6
4.2	0	0	.2	14	1.9	8.8
4.4	1	0	.1	13	1.7	6.9
4.6	1	0	0	7	.9	5.9
4.8	0	0	0	7	.9	5
5	0	0	0	2	.2	4.7
5-6	0	0	0	13	1.7	2.9
6-7	0	0	0	6	1	1.8
7-8	0	0	0	6	.8	1
8-9	0	0	0	4	.5	.4
9-10	0	0	0	3	.4	0
Maximum		4.5			11.3	

Figure 22. Frequency table and histogram for all nut detachment forces in lbs. measured for Drake almonds during 1984.



	Before	After
Number	10682	2928
Mean	.5228	1.8215
Variance	.3191	4.048

Lbs.	Num	%	Cum	Num	%	Cum
.2	3707	34.7	65.3	220	7.5	92.5
.4	3035	28.4	36.8	359	12.2	80.3
.6	1534	14.3	22.4	305	10.4	69.8
.8	785	7.3	15.1	271	9.2	60.6
1	415	3.8	11.2	170	5.8	54.8
1.2	342	3.2	8	224	7.6	47.1
1.4	217	2	5.8	205	7	40.1
1.6	177	1.8	4.3	174	5.8	34.2
1.8	98	.9	3.3	118	3.8	30.2
2	84	.8	2.7	98	3.3	26.8
2.2	71	.8	2.1	87	2.8	23.8
2.4	44	.4	1.7	103	3.5	20.4
2.6	44	.4	1.2	78	2.6	17.7
2.8	27	.2	1	53	1.8	15.8
3	20	.1	.8	38	1.3	14.5
3.2	14	.1	.7	55	1.8	12.8
3.4	11	.1	.6	52	1.7	10.8
3.6	13	.1	.5	36	1.2	8.6
3.8	8	0	.4	28	.8	8.6
4	6	0	.3	24	.8	7.8
4.2	5	0	.3	42	1.4	6.4
4.4	5	0	.2	28	.8	5.4
4.6	3	0	.2	18	.6	4.8
4.8	1	0	.2	20	.6	4.1
5	3	0	.2	8	.2	3.8
5-6	6	0	.1	45	1.5	2.3
6-7	3	0	.1	31	1	1.2
7-8	2	0	0	14	.4	.8
8-9	1	0	0	10	.3	.4
9-10	0	0	0	11	.3	0
Maximum		8.2			12.2	

Figure 23. Frequency table and histogram for all nut detachment forces in lbs. measured for All almonds during 1984.