

PAPAYA PRODUCTION FORECAST  
RESEARCH PROJECT

A Progress Report

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## Introduction

This progress report summarizes data collected during the first 49 weeks of the Papaya Production Forecast Research Project. The project was initiated in March 1973 and data collection will continue through December 1974. The ultimate goal of the study is to develop a procedure that will provide production forecasts of sufficient accuracy and reliability to meet papaya industry marketing needs.

Relationships of fruit set, survival, and growth to harvest was only studied for a 6-month period. Detailed analysis of the simple and multiple relationships of data collected in advance of harvest to the harvest results will be made after all data are available. For these reasons, this report should be regarded as preliminary.

Data collection for this project was limited to the Puna district on the Island of Hawaii. The district normally produces approximately 90 percent of the State's papaya crop.

## The Sample

The population sampled consisted of all papaya trees in Puna district fields which were planted from September 1970 through November 1972. Identification of papaya operations with these plantings was based upon an acreage record as of September 1, 1972. The plantings from September through November 1972 were considered as expected plantings over the next three months. The population was stratified into two age groups, trees planted before June 1972 and trees planted from June 1 through November 1972.

The trees were sampled in each stratum by a two-stage process. The first stage involved probability selection of operations with any plantings in the respective stratum. The operations were sampled with replacement and with probabilities proportional to their total papaya acreage as of September 1, 1972. Thus, an operation could be selected more than once in each stratum and could be selected for both strata if it had trees in the two age groups. Ten operation selections were made in each stratum.

The second and final stage of sampling involved approximately equal probability selection of tree positions from among all trees of the age group for which an operation had been selected. Three tree positions were randomly located within an operation each time the operation was selected. Sixty tree positions were initially selected in the district, 30 in each stratum.

## Collection of Data

Data collection involved weekly visits to the sample trees so fruit could be harvested on a schedule approximating normal harvesting intervals. On each visit to the sample trees, two types of data were collected: (1) aggregate tree data, and (2) detailed fruit data. Aggregate tree level observations consisted of the number of fruit set since the preceding visit and number and weight of harvestable fruit by grades. Detailed fruit data were obtained on

a non-random sample of fruit set each visit. A newly set fruit (one set since the last visit) was tagged with a number corresponding to the visit. On each visit, growth and survival information were obtained for all previously tagged fruit. Harvest data including weight and grade were obtained for each mature tagged fruit. Detailed data collection instructions are shown in Appendix A.

### Preliminary Analysis of Aggregate Tree Data

Preliminary analysis of the aggregate tree data on set and harvest involved expanding the sample data and summing to the strata levels. The expansion was the reciprocal of the probability of selection for each sample tree. The expansion has the form

$$Y_{ijk} = \left( \frac{\sum A_{jk}}{10 A_{jk}} \right) \left( \frac{T_{jk}}{3} \right) X_{ijk} ,$$

where  $Y_{ijk}$  is the expansion for the  $i^{\text{th}}$  tree in the  $j^{\text{th}}$  operation for the  $k^{\text{th}}$  stratum,  $A_{jk}$  is the total acreage of papayas for the  $j^{\text{th}}$  operation in the  $k^{\text{th}}$  stratum,  $T_{jk}$  is the number of trees in the  $j^{\text{th}}$  operation belonging to the  $k^{\text{th}}$  age stratum and  $X_{ijk}$  is the variable to be expanded for the  $i^{\text{th}}$  tree in the  $j^{\text{th}}$  operation of stratum  $k$ .  $T_{jk}$  is the grower estimate of number of trees and not an actual count. The stratum expansion can be obtained by summing all expanded totals for each stratum,  $Y_{..k} = \sum_{j1} \sum Y_{ijk}$ .

It should be noted that these expansions do not provide a good indication of the total harvest or set in the district. For example, early in the project there are older trees which were producing fruit which were not represented in the sample. Later in the project, trees younger than those sampled are first setting and later producing fruit. For research purposes the sample was selected not to represent the producing population of trees, but to study relationships between set and subsequent harvest on a sample of trees. It should also be noted that the stratum expanded totals are subject to sampling error.

Figures 1 and 2 which follow show the aggregate relationships of changes in week-to-week number of fruit set and weight of number 1 and number 1 and 2 papayas harvested. The figures illustrate the similarity in the week-to-week set level and weight of harvested papayas 22 or 23 weeks later. It also shows the gap between papayas set and those with significant harvestable value. Seasonal highs and lows for both set and harvest are evident. Tables 1 and 2 show the expanded set and harvest data for the first 49 visits for the younger and older tree strata, respectively.

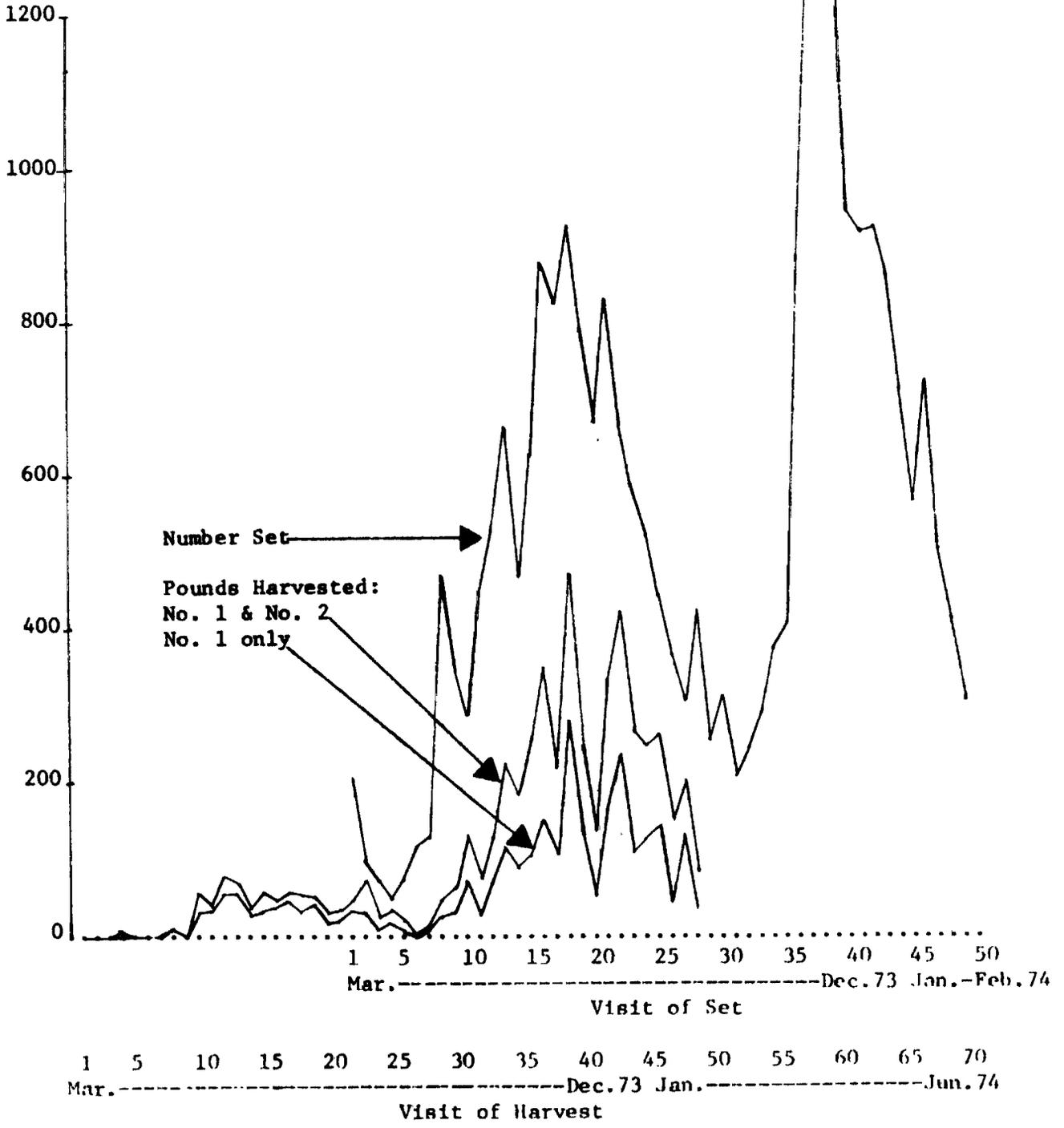


Figure 1.--Thousands of papayas set, thousands of pounds harvested of Number 1 fruit and Number 1 and 2 fruit by visits, younger tree stratum.

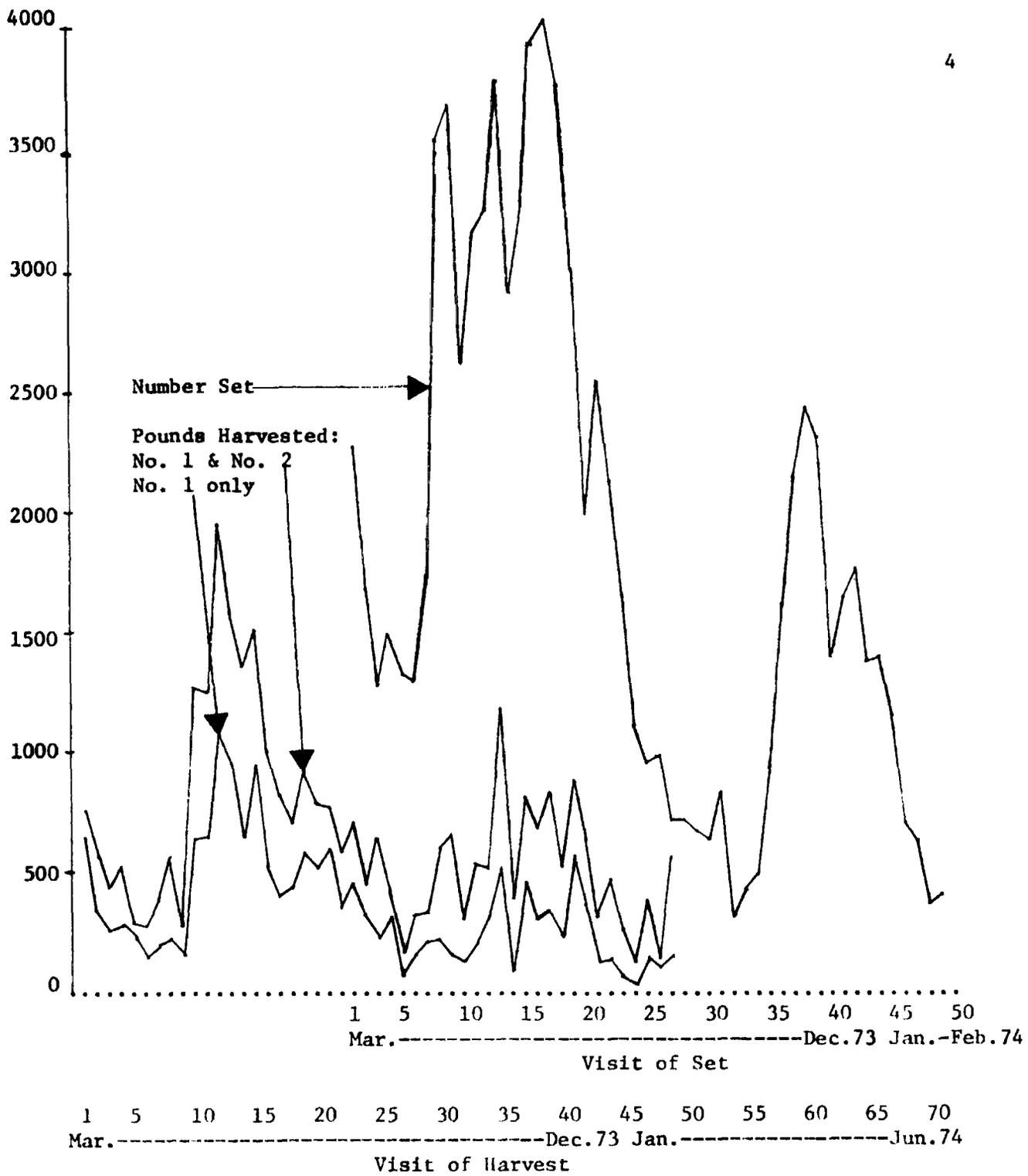


Figure 2.--Thousands of papayas set, thousands of pounds harvested of Number 1 fruit and Number 1 and 2 fruit by visits, older tree stratum.

Table 1.--Expanded number of papayas set and number and pounds harvested by grade classes, younger tree stratum, Puna district, March 1973 - February 1974

Visit number	Number of papayas			Weight of papayas			
	Set	Harvested			Harvested		
		#1 grade	#1 and #2:All mature	grades : fruit	#1 grade	#1 and #2:All mature	grades : fruit
		Thousands	Thousands	Thousands	Thousand pounds	Thousand pounds	Thousand pounds
1	201	0	0	0	0	0	
2	100	0	0	0	0	0	
3	75	0	0	0	0	0	
4	49	0	5	5	6	6	
5	75	0	0	0	0	0	
6	119	0	0	5	0	4	
7	127	0	0	0	0	0	
8	469	5	5	5	7	7	
9	342	0	0	0	0	0	
10	285	27	59	59	27	59	
11	445	27	32	32	33	38	
12	535	32	48	59	56	79	
13	664	43	54	86	56	69	
14	467	21	32	38	26	36	
15	628	21	43	54	31	58	
16	879	27	32	48	39	45	
17	827	32	43	64	46	59	
18	926	27	48	59	31	55	
19	790	32	43	64	40	50	
20	671	16	27	54	18	31	
21	833	16	32	59	20	38	
22	666	27	43	80	32	50	
23	590	27	64	86	29	74	
24	522	5	16	21	9	23	
25	442	16	32	80	18	35	
26	365	5	21	43	5	20	
27	307	0	0	5	0	0	
28	422	5	11	38	6	13	
29	257	14	30	46	22	45	
30	314	20	42	101	32	61	
31	210	58	112	159	68	132	
32	244	27	68	121	27	79	
33	291	50	92	195	70	129	
34	377	88	167	298	117	223	
35	406	62	126	197	87	183	
36	883	71	187	287	104	259	
37	1280	108	240	439	153	353	
38	1238	83	168	297	108	220	
39	1325	196	346	486	280	474	
40	947	109	189	307	138	241	
41	920	45	114	232	55	139	
42	926	124	261	376	161	335	
43	864	177	319	456	238	422	
44	717	82	205	300	108	265	
45	565	90	182	315	124	248	
46	723	110	211	283	141	261	
47	502	37	123	238	43	155	
48	415	104	162	195	133	202	
49	305	30	70	121	38	86	

Table 2.--Expanded number of papayas set and number and pounds harvested by grade classes, older tree stratum, Puna district, March 1973 - February 1974

Visit number	Number of papayas				Weight of papayas		
	Set	Harvested			Harvested		
		#1 grade	#1 and #2:All mature grades	fruit	#1 grade	#1 and #2:All mature grades	fruit
		Thousands			Thousand pounds		
1	2270	560	689	718	636	761	775
2	1680	320	533	578	349	567	606
3	1287	248	375	436	261	437	493
4	1480	221	438	458	290	538	557
5	1324	206	254	322	242	297	341
6	1294	133	258	298	149	291	321
7	1738	161	343	512	192	403	556
8	3539	165	435	493	231	564	623
9	3689	156	269	525	169	290	507
10	2635	571	1230	1362	645	1267	1364
11	3155	553	1101	1181	655	1250	1358
12	3257	701	1229	1480	1077	1942	2195
13	3785	812	1362	2031	961	1578	2218
14	2964	510	1039	1357	661	1356	1682
15	3270	742	1197	1486	944	1509	1826
16	3935	442	825	1136	530	1005	1350
17	4040	371	749	1111	413	819	1221
18	3758	382	643	1069	437	705	1053
19	3012	503	787	1069	583	919	1153
20	1994	440	680	1063	524	785	1178
21	2548	501	669	758	595	777	863
22	2196	308	504	964	362	588	1152
23	1657	380	622	850	448	710	948
24	1108	250	356	654	318	448	763
25	959	221	592	1219	235	638	1196
26	984	300	412	827	308	423	797
27	729	57	161	449	65	181	448
28	727	135	291	566	166	323	541
29	676	150	246	544	217	331	647
30	642	179	477	992	229	610	1155
31	843	121	523	1010	159	650	1072
32	314	113	281	1135	129	310	1170
33	433	169	415	1285	213	540	1329
34	492	243	385	1086	323	518	1145
35	937	342	883	1770	511	1178	2200
36	1617	77	331	1416	99	402	1535
37	2150	370	676	1482	457	805	1760
38	2434	231	540	1434	306	685	1593
39	2321	249	665	1449	352	842	1581
40	1406	203	436	882	246	536	976
41	1652	438	700	1349	567	871	1540
42	1764	283	504	919	370	633	1085
43	1378	108	256	633	130	315	721
44	1409	114	385	488	139	479	591
45	1156	48	181	479	68	266	610
46	720	29	106	218	41	127	261
47	632	112	309	502	142	379	616
48	368	94	121	150	118	142	168
49	412	126	458	614	158	568	754

### Preliminary Analysis of Tagged Fruit Data

Data collected on tagged fruit record the life history of individual papayas. Each tagged fruit's set, survival (or type of loss), growth and harvest is revealed in weekly installments. This history is obtained for one of the newly set fruit on each tree for each weekly visit. The detailed observations provide information potentially useful in: (1) adjusting set for survival, (2) predicting harvest grade, (3) predicting time from set to harvest, and (4) projecting the number of fruit surviving to maturity.

The utility of the number of fruit set adjusted for survival has yet to be investigated. Presumably, number set adjusted for loss up to one month after set would be more useful in forecasting the harvest results than unadjusted set. Likewise, set adjusted for loss up to two months later would be even a better predictor. However, the length of time prior to harvest is becoming shorter so ability to predict must be improved by some sufficient increment.

Of the fruit surviving, rate of growth or nature of the growth curve does not appear to provide an indication of the potential harvest grade. Plans have been made to collect limited information on prospective harvest grade during the last six months of the research project. Prospective grade will be determined on the fifth, tenth, fifteenth and twentieth visits after tagged fruit are set.

Tables 3 and 4 illustrate the use of tagged fruit data in predicting the time from set to harvest. This data is based on knowing the harvest visit and as such is not a prediction. However, the uniformity of length of time between set and harvest will be useful in forecasting production. The aggregate data on set and harvest and the detailed fruit observations indicate a set to harvest period of 22 weeks for the younger trees and 23 weeks for the older tree stratum. At least this is the case for the August 1973 through January 1974 harvest period.

Potential use of detailed tagged fruit data for projecting the number of fruit surviving will be investigated when all data are available. These projections will involve a time dependent survival model.

Tables 5 and 6 show fruit survival and mean length of surviving fruit during the first ten weeks. Number harvested is also shown. Failure of fruit survival is usually caused by individual fruit loss. However, loss and abandonment of trees are also involved. Abandonment of trees is a more common cause of fruit loss for the later visits shown in Table 6.

### Analysis of Photographic Data

Photographic data were collected when the initial sample of trees was located in late February 1973. Collection of the data involved color photography of all sample trees with fruit. Detailed instructions for acquiring photography and counting of fruit on photographic slides are shown in Appendix C.

Table 3.--Number of tagged papayas harvested by visit set and visit harvested, younger tree stratum, Puna district, March 1973 - February 1974

		Visit Set																															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
	19 :	1	1																														
	20 :																																
	21 :	1					1																										
	22 :	1	1			1																											
	23 :	1																															
	24 :	1	1																														
	25 :	1	3	2	3	1																											
	26 :	1	2	1		2	1																										
	27 :				1		2																										
	28 :			1		2	1	3	1																								
	29 :					2	3	1																									
	30 :					3	1	2	1																								
Visit Harvested	31 :								3	2	1																						
	32 :				1			2	3	1	2	1																					
	33 :								1	3	6		1																				
	34 :								1	2		4	1	1	1																		
	35 :										1	2	5	3	1	1																	
	36 :												3	5	4	2	1								1								
	37 :													2	4	5	4	2															
	38 :														2	4	3	2	2														
	39 :													1	2	4	4	4	4	1													
	40 :																3	2	3	7	3	1											
41 :																1	5	7	4	1	3				1								
42 :																	2	1	3	7	3	5	2										
43 :																		1	4	5	3	1	1	1	1	1							
44 :																				1	2	7	2	3									
45 :																				2	1	1	3	3	2								
46 :																						3	2	2	2	4							
47 :																							1	4	2	3	1	2					
48 :																									1		3	2					
49 :																									3	2	3	1	1				
	:																																



Table 5.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and the number harvested, younger tree stratum, Puna district, March 1973 - February 1974

Visit set	Number tagged	Number surviving and mean length <u>l</u> / during the first nine weeks after set										Number surviving to harvest
		1	2	3	4	5	6	7	8	9		
1	No. : 10	10	10	10	10	10	10	10	10	10	10	7
	Size :		58	68	76	85	97	107	116	122		
2	No. : 9	9	9	9	9	9	9	9	9	9	9	8
	Size :		56	68	79	90	98	109	117	122		
3	No. : 7	7	6	5	4	4	4	4	4	4	4	4
	Size :		53	65	82	93	102	108	114	125		
4	No. : 7	7	6	6	5	5	5	5	5	5	5	4
	Size :		63	73	87	97	105	113	126	134		
5	No. : 9	9	8	8	8	8	7	7	7	7	7	7
	Size :		62	73	83	90	99	112	120	128		
6	No. : 11	11	11	11	11	10	10	10	10	10	10	10
	Size :		63	74	81	91	101	112	119	125		
7	No. : 11	10	10	10	10	10	10	10	10	10	10	7
	Size :		65	76	87	98	108	117	124	133		
8	No. : 13	11	11	11	11	11	11	11	11	11	11	9
	Size :		62	73	83	91	101	108	115	120		
9	No. : 14	14	14	13	13	13	13	11	11	11	11	8
	Size :		64	75	84	91	99	108	114	119		
10	No. : 15	14	13	12	10	10	8	8	7	7	7	7
	Size :		61	72	82	89	101	108	117	124		
11	No. : 14	12	12	11	11	11	11	11	10	10	10	9
	Size :		71	82	90	100	108	115	122	128		
12	No. : 16	14	14	11	10	10	10	10	10	10	10	10
	Size :		64	74	87	96	107	115	122	127		
13	No. : 18	17	15	14	14	14	14	14	14	14	14	14
	Size :		71	87	98	108	117	124	128	131		
14	No. : 19	18	16	15	15	15	15	15	15	15	15	15
	Size :		69	83	96	106	114	119	125	130		
15	No. : 20	20	19	17	17	17	17	16	16	16	16	15
	Size :		68	83	94	102	107	117	123	128		
16	No. : 20	20	20	18	17	17	17	17	17	17	17	17
	Size :		72	84	93	99	106	114	119	123		
17	No. : 21	21	19	19	18	18	18	18	18	18	18	17
	Size :		73	85	93	101	108	115	120	124		
18	No. : 21	21	21	21	19	19	19	19	19	19	19	18
	Size :		77	83	93	103	110	116	122	126		
19	No. : 24	24	23	22	22	22	22	22	22	22	22	19
	Size :		69	78	87	95	103	110	116	122		
20	No. : 24	24	22	22	22	22	22	22	22	22	22	19
	Size :		65	77	86	95	103	109	119	127		
21	No. : 25	24	20	20	20	20	19	18	18	17	17	13
	Size :		66	78	86	95	103	116	123	131		
22	No. : 24	24	22	21	21	21	21	21	21	21	21	19
	Size :		65	75	89	98	109	118	128	133		
23	No. : 23	22	18	17	17	17	17	17	17	17	17	14
	Size :		63	75	86	98	108	119	125	133		

Table 5.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and the number harvested, younger tree stratum, Puna district, March 1973 - February 1974--Continued

Visit set	Number tagged	Number surviving and mean length <u>l</u> / during the first nine weeks after set										Number surviving to harvest
		1	2	3	4	5	6	7	8	9		
24	No. : 21	20	19	19	19	18	17	17	17	17	17	16
	Size :		65	75	88	100	114	121	128	134		
25	No. : 21	19	17	17	17	17	17	17	17	17	17	<u>2/13</u>
	Size :		64	78	90	100	109	117	125	132		
26	No. : 21	20	19	19	19	19	19	19	19	19	19	<u>2/17</u>
	Size :		62	75	89	98	106	116	123	128		
27	No. : 16	16	16	16	16	16	16	16	16	16	16	<u>2/15</u>
	Size :		64	82	92	101	111	117	124	131		
28	No. : 18	17	17	17	17	17	17	17	17	17	17	<u>2/16</u>
	Size :		64	77	88	98	106	115	122	127		
29	No. : 16	14	13	11	11	11	11	11	11	11	11	<u>2/11</u>
	Size :		64	80	93	101	110	116	122	128		
30	No. : 17	17	15	15	15	15	15	15	15	15	15	<u>2/13</u>
	Size :		66	82	94	104	114	121	128	135		
31	No. : 14	13	13	13	13	13	13	13	13	13	13	<u>2/13</u>
	Size :		69	83	96	108	115	123	130	135		
32	No. : 14	14	14	14	12	12	12	12	12	12	12	<u>2/10</u>
	Size :		66	78	90	99	108	116	124	130		
33	No. : 14	14	14	14	14	14	14	14	14	14	14	<u>2/12</u>
	Size :		72	85	95	106	116	124	132	137		
34	No. : 18	18	18	17	17	17	16	15	15	15	15	<u>2/15</u>
	Size :		69	81	93	104	112	120	127	132		
35	No. : 22	22	22	22	22	21	21	21	21	20	20	<u>2/19</u>
	Size :		67	81	93	104	113	123	129	133		
36	No. : 27	27	25	25	24	24	24	23	22	22	22	<u>2/22</u>
	Size :		69	83	96	107	115	122	128	133		
37	No. : 27	27	26	23	21	21	19	18	18	18	18	<u>2/18</u>
	Size :		70	81	95	104	113	119	125	131		
38	No. : 28	27	25	24	24	24	23	22	22	21	21	<u>2/21</u>
	Size :		72	83	92	102	108	114	121	127		
39	No. : 28	27	21	19	18	18	18	18	17	17	17	<u>2/17</u>
	Size :		74	83	92	101	108	116	123	130		
40	No. : 27	25	22	20	19	18	18	18	18	18	18	<u>2/18</u>
	Size :		68	80	91	102	111	118	126	131		
41	No. : 26	24	24	23	21	21	20	19	19	19	19	<u>2/19</u>
	Size :		69	81	92	102	111	119	126			
42	No. : 26	26	24	23	23	20	20	20	20	20	20	<u>2/20</u>
	Size :		67	79	90	100	109	117				
43	No. : 26	25	22	21	19	19	19	19	19	19	19	<u>2/19</u>
	Size :		73	83	96	108	116					
44	No. : 23	23	22	16	16	16	16	16	16	16	16	<u>2/16</u>
	Size :		71	84	95	104						
45	No. : 24	22	19	16	16	16	16	16	16	16	16	<u>2/15</u>
	Size :		74	86	96							

Table 5.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and the number harvested, younger tree stratum, Puna district, March 1973 - February 1974--Continued

Visit set	Number tagged	Number surviving and mean length <u>1/</u> during the first nine weeks after set									Number surviving to harvest
		1	2	3	4	5	6	7	8	9	
46	No. : 24	23	22	<u>2/21</u>							
	Size :		71	82							
47	No. : 20	20	<u>2/20</u>								
	Size :		68								
48	No. : 21	<u>2/21</u>									
	Size :										
49	No. : <u>2/21</u>										
	Size :										

1/ Size data were first obtained on the second visit following tagging of the newly set fruit. It is the mean length of surviving fruit in millimeters.

2/ Number of fruit surviving or harvested through visit 49.

Table 6.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and number harvested, older tree stratum, Puna district, March 1973 - February 1974

Visit set	Number tagged	Number surviving and mean length $\bar{x}$ during the first nine weeks after set									Number surviving to harvest
		1	2	3	4	5	6	7	8	9	
1	No. : 25	25	20	20	20	20	20	20	19	19	16
	Size :	61	75	84	95	107	116	123	130		
2	No. : 23	22	21	20	20	19	17	17	17	17	16
	Size :	59	68	80	91	103	108	117	124		
3	No. : 24	23	21	20	19	17	15	15	15	15	15
	Size :	58	74	83	95	105	112	121	128		
4	No. : 24	24	20	17	17	16	16	15	15	15	14
	Size :	61	77	86	95	104	111	119	127		
5	No. : 24	23	19	17	17	17	16	16	16	16	14
	Size :	67	80	90	97	110	118	127	133		
6	No. : 23	22	22	20	20	18	18	18	18	18	15
	Size :	66	76	85	97	105	114	121	129		
7	No. : 23	23	21	18	17	16	15	15	14	14	12
	Size :	68	81	93	105	116	124	133	139		
8	No. : 26	26	25	22	21	20	19	19	19	19	15
	Size :	66	77	87	97	107	115	123	131		
9	No. : 26	26	26	24	24	22	21	21	20	20	18
	Size :	66	76	86	96	105	113	122	129		
10	No. : 26	26	23	20	19	18	17	17	17	16	14
	Size :	63	75	83	93	104	114	120	127		
11	No. : 26	26	26	24	22	20	19	18	17	17	15
	Size :	60	70	83	95	106	112	120	126		
12	No. : 26	26	25	22	17	17	16	15	15	15	14
	Size :	63	74	88	102	109	121	127	132		
13	No. : 26	26	24	20	17	17	17	17	17	16	13
	Size :	65	79	93	103	112	119	125	132		
14	No. : 26	25	23	18	16	16	16	16	16	16	16
	Size :	65	81	94	104	111	119	127	132		
15	No. : 26	26	25	25	22	22	22	21	21	21	20
	Size :	69	80	95	104	112	122	128	133		
16	No. : 26	26	25	18	18	18	15	15	15	15	13
	Size :	66	80	88	96	103	110	116	120		
17	No. : 26	26	22	21	21	20	20	20	20	20	19
	Size :	72	83	92	104	111	117	122	126		
18	No. : 26	24	23	22	19	18	18	18	18	18	14
	Size :	74	82	94	103	111	117	122	126		
19	No. : 26	26	23	20	20	20	20	20	20	20	15
	Size :	74	83	93	101	107	113	118	126		
20	No. : 26	23	18	17	17	16	16	16	16	16	10
	Size :	73	86	95	102	109	115	123	131		
21	No. : 26	25	23	21	20	19	19	19	19	19	11
	Size :	69	80	90	98	107	116	124	133		
22	No. : 26	25	25	24	24	24	23	23	22	22	13
	Size :	69	79	90	99	110	119	129	136		
23	No. : 25	23	21	21	20	20	20	18	18	17	9
	Size :	68	79	90	102	113	121	130	135		

Table 6.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and number harvested, older tree stratum, Puna district, March 1973 - February 1974--Continued

Visit set	Number tagged	Number surviving and mean length $\bar{x}$ during the first nine weeks after set										Number surviving to harvest
		1	2	3	4	5	6	7	8	9		
24	No. : 25	23	20	19	17	17	17	17	17	17	17	<u>2/9</u>
	Size :		60	72	88	100	111	119	126	134		
25	No. : 23	19	18	15	15	15	15	14	14	14	14	<u>2/8</u>
	Size :		63	78	89	102	110	118	125	130		
26	No. : 24	21	18	18	18	18	18	18	17	17	17	<u>2/10</u>
	Size :		64	78	91	102	111	118	125	132		
27	No. : 21	21	18	18	18	18	18	18	18	18	18	<u>2/11</u>
	Size :		68	82	94	104	114	122	129	135		
28	No. : 20	16	16	15	14	14	14	14	14	14	14	<u>2/8</u>
	Size :		67	83	95	106	113	119	126	132		
29	No. : 15	15	15	13	13	13	12	12	12	12	12	<u>2/7</u>
	Size :		68	79	91	101	107	116	124	129		
30	No. : 15	15	13	11	11	11	11	11	11	11	11	<u>2/6</u>
	Size :		68	82	95	107	116	122	127	133		
31	No. : 14	14	13	13	13	11	10	10	10	9	9	<u>2/7</u>
	Size :		62	75	86	100	109	117	123	127		
32	No. : 9	9	8	7	7	7	7	7	7	7	7	<u>2/4</u>
	Size :		68	79	92	102	111	117	123	129		
33	No. : 10	10	10	10	7	7	7	6	6	6	6	<u>2/4</u>
	Size :		68	81	93	103	112	121	128	134		
34	No. : 15	15	15	12	12	11	8	6	6	5	5	<u>2/5</u>
	Size :		64	78	88	101	110	124	131	137		
35	No. : 20	20	19	19	19	15	12	11	10	10	10	<u>2/9</u>
	Size :		66	77	86	99	114	122	128	134		
36	No. : 19	18	17	16	14	13	11	10	9	9	9	<u>2/9</u>
	Size :		66	77	91	105	115	124	131	135		
37	No. : 22	21	19	16	12	10	9	7	6	6	6	<u>2/6</u>
	Size :		68	82	96	107	114	121	128	132		
38	No. : 22	21	17	14	14	13	11	11	11	11	11	<u>2/11</u>
	Size :		67	83	95	102	109	118	125	131		
39	No. : 24	21	16	15	15	13	12	12	12	12	12	<u>2/12</u>
	Size :		69	80	91	102	112	121	128	134		
40	No. : 20	19	15	14	13	12	12	12	12	12	12	<u>2/12</u>
	Size :		67	77	89	99	108	116	122	129		
41	No. : 20	18	16	12	12	12	12	12	12	12	12	<u>2/12</u>
	Size :		67	82	93	103	110	118	125			
42	No. : 18	16	12	11	11	11	11	11	11	11	11	<u>2/10</u>
	Size :		69	83	94	103	112	121				
43	No. : 17	15	11	11	9	9	9	9	9	9	9	<u>2/9</u>
	Size :		65	75	88	96	106					
44	No. : 15	13	13	8	8	8	8	8	8	8	8	<u>2/8</u>
	Size :		70	85	96	108						
45	No. : 15	15	10	10	10	10	10	10	10	10	10	<u>2/9</u>
	Size :		71	81	91							

Table 6.--Number of newly set papayas tagged, their survival and mean length during the first ten weeks of growth and number harvested, older tree stratum, Puna district, March 1973 - February 1974--Continued

Visit set	Number tagged	Number surviving and mean length <u>1/</u> during the first nine weeks after set									Number surviving to harvest	
		1	2	3	4	5	6	7	8	9		
46	No. : 14	14	13	<u>2/10</u>								
	Size :		70	85								
47	No. : 13	12	<u>2/10</u>									
	Size :		67									
48	No. : 13	<u>2/13</u>										
	Size :											
49	No. : <u>2/12</u>											
	Size :											

1/ Size data were first obtained on the second visit following tagging of the newly set fruit. It is the mean length of surviving fruit in millimeters.

2/ Number of fruit surviving or harvested through visit 49.

The objective of collecting photographic data was to obtain an indication of its utility in forecasting papaya production. Photography of trees may provide a cheap and efficient method of estimating the number of fruit per tree. This might involve total fruit per tree or some subset of fruit set during various time periods. For example, if a relatively large survey is required to estimate set per tree with the necessary precision, tree photography might be useful in minimizing costs. A double sampling design might be used where a large sample of trees are photographed to obtain photo-counts and a smaller subsample of these trees are actually counted in the field.

This initial study was limited to estimating the total number of fruit per tree. In late February, the younger trees were from three to nine months old and the older group ranged up to 30 months of age. Only trees with fruit (as counted in the field) were photographed. Nine trees had fruit in the younger tree stratum and 29 of the 30 older trees had fruit.

Counts of visible papayas based on color photography of one side of these trees showed a strong relationship with field counts of total fruit. Correlation coefficients were estimated at .96 for all trees, .95 for the younger tree stratum and .92 for older trees. Corresponding 95 percent confidence intervals of these estimates were .94-.98, .90-.98 and .84-.96, respectively. The estimated linear regression of field counts (Y) as dependent upon photo-counts (X) were,

$$Y = -1.298 + 1.955X \text{ for the younger stratum, and}$$

$$Y = 3.220 + 1.620X \text{ for the older tree stratum.}$$

An experienced photo interpreter, Edward Camara of the Research and Development Branch, performed the photo-counts according to the instructions in Appendix B. Number of fruit on the younger trees was much less than the number on most older trees. Time to count fruit for each tree position, excluding set up time, averaged 2.8 and 4.5 minutes for the younger and older trees, respectively.

#### Preliminary Conclusions

The development of objective methods of forecasting papaya production seems possible. Several advantages which favor the forecasting of production prior to harvest are:

1. An essentially complete list of papaya growers exists. Such a list would be useful as a first stage sampling frame.
2. Acreage information is available. Detailed papaya acreage data are collected for the Island of Hawaii.
3. The period from fruit set until maturity is quite uniform. For useful forecasts both the amount and timing of production are essential. The relatively uniform length of the growth period makes timing of harvest less speculative.

4. Week-to-week changes in the number set correspond to similar changes in pounds of number 1 fruit and grade 1 and 2 papayas subsequently harvested.

Several disadvantages which need to be considered are:

1. The percentage of harvested fruit grading number 1 seems to vary greatly at different times of the year. The proportion of the total number of fruit graded number 1 exceeded 50 percent on most visits during the spring of 1973, was near 50 percent during June and July and then dropped to less than 40 percent for most of the August through February period. The repeatability of this seasonal pattern can not be studied until more data becomes available. Data to be collected on prospective grades may provide information useful in overcoming this disadvantage.
2. Variability between papaya trees, plantings and operations may necessitate a rather large sample survey.
3. Data may need to be collected for an extended period of time before sufficient information is available to develop reliable forecast models. The length of the period will depend upon the number of models needed for different times of the year and different age trees.

Further analysis of the data now available and for the full 22 months of the project will provide more information on the strength of the advantages. Hopefully, information useful in minimizing the disadvantages and further defining them can be secured.

#### Acknowledgements

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## APPENDIX A

PAPAYA PRODUCTION FORECAST  
RESEARCH PROJECT

## DATA COLLECTION INSTRUCTIONS

Objective

The objective of the Papaya Production Forecast Research Project is to collect tree and fruit data necessary for evaluation of the ability to forecast papaya production prior to harvest. Research utilizing this basic data is designed to develop a procedure that will yield production forecasts of sufficient accuracy and reliability to meet papaya industry needs.

Cooperation

Cooperation of and with operators of papaya operations in this survey is essential. Opportunities to further cooperation with operators and their employees should be utilized. Operators have agreed not to harvest fruit from the individual trees in the survey. Their employees should be aware of this restriction on harvest activities, but may need to be reminded occasionally. The operators have been assured that harvested fruit will remain on their property.

The Sample

Eleven operations have been sampled in the Puna district. These operations include two age groups of trees; basically those planted before June 1, 1972 and those planted more recently. A number of trees have been selected for each operation; varying from three to 15. A total of 60 trees will be observed during the survey.

Schedule of Survey

The survey is designed to provide weekly data on fruit set, growth, survival and harvest. So that the time period between visits for each tree is one week, a regular schedule of visits to the individual trees and operations must be observed.

Identification of Trees

Individual trees for which data is to be collected will be spray painted with two red bands around the trunk. The tree will be identified by a seven-digit code. The first digit indicates the age group of the tree. Trees in younger plantings are identified by a "1" and those in older plantings by a "2". The next four digits identify the operation and the last two digits identify the tree within the operation. For example, 1-2912-42 identifies a younger tree in operation 2912. It is essential that the data for an individual tree be recorded on the correct form. The tree identification number is shown on the tape around the tree trunk. If it becomes difficult to read the number, mark it again.

### Safety

Work on this survey will be performed as a two-man team. This will allow the person on the ladder to make counts and measurements while the person on the ground assists with counting, records data, and steadies the ladder. Care should be taken in placing the ladder on a firm base. Work at a uniform speed, going from one task to another without delay; but do not hurry. Especially, when working with tall trees on sloping terrain, take time to gather accurate data in a safe manner. The time entries on the form will provide a measure of costs in terms of minutes. Use military or 24-hour time.

### Care of Fruit

It is essential that handling of the tree and fruit during data collection does not affect productivity of the tree. Caution must be used in handling of newly set fruit. The measurement of fruit length may be especially difficult to make without disturbing the attachment of the fruit to the tree. Measure length of fruit without moving the fruit if at all possible. The sample of trees is designed to represent all trees. If data collection activities affect the trees productivity, then this will not be possible.

### Collecting Data on Fruit Set

Fruit set data is an essential part of the survey. A fruit is set when the blossom has shed or the blossom breaks away from the fruit readily upon brushing its tip. If the blossom does not break away readily, the fruit is considered not yet set. Fruit set will be determined by counting all fruit which have not been marked as having been set earlier. Fruit will be marked by a rubberband. As new set fruit are counted, place a rubberband over the fruit so that it rests on the stem. This will prevent counting those fruit again on the following visit. Tag the one fruit that appears to have set first following the preceding visit (if any fruit has set during the week) with the plastic tag numbered for the visit. Care must be taken in placing the tags and rubberbands on the newly set fruit. Indicate the tagged new set fruit with an "X" in the size box corresponding to its number in the fruit growth section of the form. If no fruit are set during the week, indicate this by entering "NS" in the size box.

An alternative method of determining new fruit set may be used occasionally as a check on the method described above. It involves counting all fruit on the tree. The all fruit count less the fruit on tree at the conclusion of the preceding visit will be the number set.

Record the number of fruit thinned or lost (knocked off) when using either of the methods of determining set. Thinning should be performed with care. If non-sampled trees near the sample tree have been thinned, thinning of the sample tree's fruit should be considered. Check with your supervisor.

### Obtaining Fruit Growth Measurements

Fruit growth measurements will be obtained by measuring the distance (length) over the accessible surface of the fruit from the stem attachment to the bud axis. Fruit measurements will be obtained only for tagged fruit. The accessible surface will normally be the upward facing side of the fruit. Measure along the curved surface of the fruit and record the length in millimeters. Be sure to record the measurement for the proper fruit. Observe the tag number carefully and then check to see that the measurement is reasonable. The measurement should generally increase or at least not decrease. If the measurement is questionable, recheck the fruit tag and the measurement. As stated previously, be careful in moving fruit while making the measurement. If it becomes impossible to measure some of the fruit, check with the supervisor. Fruit are not to be measured until the second visit following the visit they were observed to be set. For example, on the 14th visit, fruit tagged on the 12th and earlier visits should be measured.

### Fruit Condition Observations

Utilize the four fruit codes shown on the bottom of the Fruit Set, Growth, and Harvest Data form and any other codes to describe any unusual observed conditions. Greater detail regarding fruit condition and/or tree condition can be described on the back of the form.

### Collecting Data on Fruit Harvested

Fruit should be harvested when they show any yellow coloration. Enter total number harvested and number by grades on the form. Weigh each grade of fruit as a group and record the weights on the form. For harvested tagged fruit, weight and grade data should be associated with the number of the fruit on the form. An "H" should be entered in the size box for the visit and the fruit number, weight and grade entered in the harvest data section. Tagged fruit should be weighed with other fruit of the same grade and alone. Definitions of the grades are shown in Department of Agriculture Regulation I, Fresh Fruits and Vegetables, Sub-Section 5.32, Standards for Hawaiian Grown Papayas.

Fruit grade is a very important indication of utilization of the crop.

### Reporting of Time

Information about the time required to complete various tasks is very important in designing an efficient procedure for developing production forecasts. The basic order of data collection operations for an individual tree is:

1. Identify tree and record the starting time.
2. Record fruit counts and tag the recently set fruit.
3. Obtain and record fruit growth measurements for all tagged fruit.
4. Record time after size measurements.
5. Harvest all fruit with yellow coloration, weigh, grade, and record on the form. Also weigh tagged fruit separately if any are harvested.
6. Record the time after harvest and grading.

Total time and mileage on this project should be shown on the Papaya Research Time and Mileage Certificate. Prepare in triplicate. The original should be reviewed and initialed by the supervisor and submitted to the PAC. Send the first carbon to the Honolulu office. The third copy should be kept by the contractor.

## APPENDIX B

PAPAYA PRODUCTION FORECAST  
RESEARCH PROJECT

## INSTRUCTIONS FOR PHOTOGRAPHIC DATA COLLECTION

Objective

The objective of collecting photographic data is to evaluate its use in forecasting papaya production prior to harvest. Photography of trees may provide a cheap and efficient method of estimating the number of fruit per tree. If the number of fruit per tree is an important variable in determining production of the crop, then photo-counts of fruit would be a possible method of acquiring data on this variable. Photography may provide a good method of estimating the number of fruit set over a relatively short period of time; however, the initial evaluation will center on estimating the number of fruit per tree.

Acquiring Photography

Color photography will be acquired for all sample trees with fruit at various times during this research project. Photographs of the trees should be taken so that a clear picture of the fruit column is obtained. This will involve selecting a side of the tree to photograph based on the following criteria:

1. Maximum lighting is reaching the fruit photographed. This is especially critical on cloudy days.
2. Not facing the sun is important on bright days.
3. The fruit are visible. This may require selecting a more open side of the tree (a side with fewer leaves).

Selecting a side of the tree should not be based on the number of fruit visible. If there are two or more trees in one tree position, obtain individual photographs for each tree. Try to obtain as close a picture as possible of the fruit column in each tree photographed, without (1) excluding any fruit from the view, or (2) missing newly set fruit near the top of the column. Keep an accurate record of the order in which trees are photographed and the roll of film used, as shown below:

<u>Tree I.D. No.</u>	<u>Film Roll</u>	<u>Exposure Number</u>
2-2912-12	2	10
2-2912-11	2	11
2-2912-13	2	12, 13
1-5030-22	2	14
1-5030-13	2	15

Counting Fruit on Photographic Slides

The photography acquired in the field will be utilized in the color slide format to obtain counts of visible papayas. Photo-counts can be made by

projecting the slides on a screen a suitable distance from the projector. By projecting the image upon a screen with horizontal lines, the fruit can be counted by sections of the fruit column. This method will prevent counting of fruit more than once, assure that all visible fruit are counted and break the counting job into manageable portions.

All visible fruit that have set should be counted. A fruit is defined as set when the blossom has shed or the blossom breaks away from the fruit readily upon brushing its tip.

The slide should be presented to the interpreter along with the Fruit Count form. The tree I.D. Number should be entered on the form before it is assigned to the interpreter. When prepared to begin counting, the interpreter should enter the starting time on the form. Counts of the fruit in each section should be made in a systematic fashion and entered in the corresponding section of the form. A fruit should be counted only in one section, usually the section in which more than 50 percent of the visible portion appears. The time completed and the date should be entered when through counting. The interpreter should check the tree I.D. Number on the slides, when removing them from the projector, to be sure they correspond to the number on the forms. After checking this last item, the interpreter should initial near the bottom of the form.

Photo interpretation should not be scheduled for longer than one hour sessions. It is suggested that an hour be scheduled in the morning and in the afternoon. Two sessions of about a half hour may be substituted for the one hour session.