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Factors Influencing Variety Selection in the California Processing Tomato Industry

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Mark Phillips

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Doctoral degree in Resource Development

Raymond D Vlasin
Major professor

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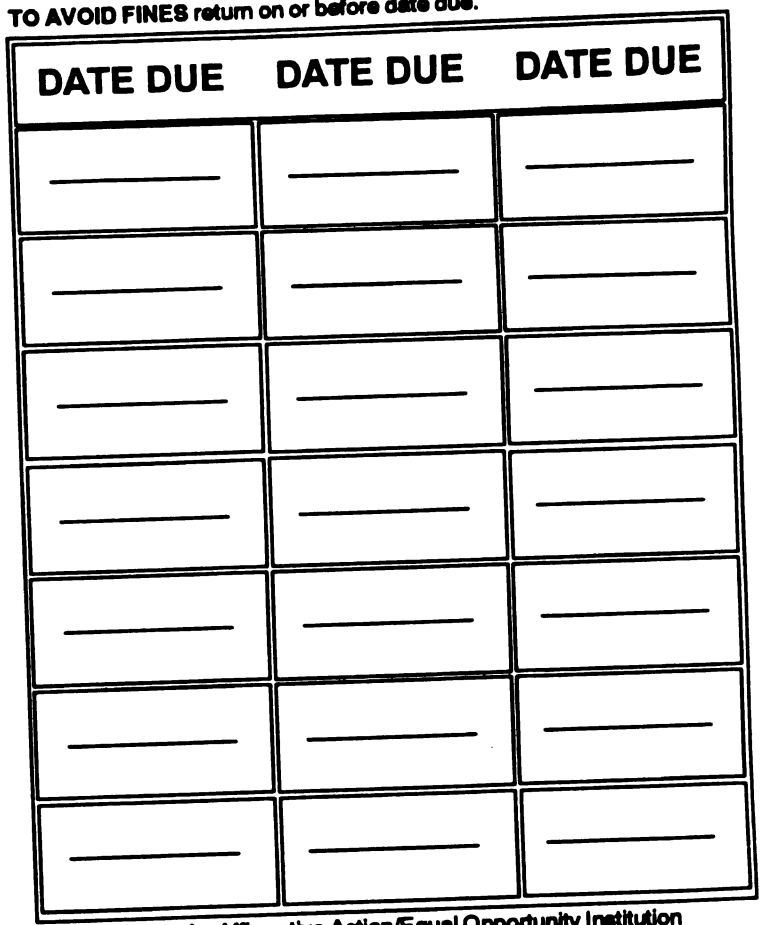

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FACTORS INFLUENCING VARIETY SELECTION IN THE CALIFORNIA PROCESSING TOMATO INDUSTRY

By

Mark Phillips

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Resource Development

1997

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ABSTRACT

FACTORS INFLUENCING VARIETY SELECTION IN THE CALIFORNIA PROCESSING TOMATO INDUSTRY

By

Mark Phillips

Between 1965 and 1995 California's share of total U.S. processing tomato production increased from slightly less than 56 percent to over 92 percent. The state has been able to maintain its dominant market position by introducing a wide range of technological innovations including improved varieties. Although hundreds of new varieties have been released, only a few have managed to capture a significant share of the market. In addition, the reign of even the most successful varieties usually lasts only a few years before they are replaced by new and improved varieties.

Varietal choices are hampered by a number of different factors. Several potential factors include the following. First, growers and processors are interested in somewhat different sets of characteristics. Second, due to the small differences among varieties, it is difficult to identify the best variety choices. Third, the performance of varieties in field trials may not reflect how well the same varieties will perform in growers' fields. Fourth, due to the large number of variety choices, growers and processors may lack the resources to adequately sift through the available information to identify the best varieties.

If there are no constraining factors, one would expect the varieties which earn growers the most profits to contribute the largest shares of total production (load shares). In addition, since grower profitability and yield are highly correlated, one

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would expect the highest yielding varieties to have the largest load shares. However, these relationships are not observed. Rather, it is hypothesized that there is virtually no correlation between grower profitability and load share. Consequently, yield and profitability play an insignificant role in variety selection. The above result is supported by the finding that yield's estimated implicit prices at the regional and state levels are insignificant and hence do not influence seed prices.

The above result is important for several reasons. First, a considerable amount of time is spent by the processing tomato industry to identify high yielding varieties. Second, given the current glut of processing tomatoes available on the world market, growers might prefer varieties that reduce their production costs or that reduce crop damage.

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Many other people helped me along the way. First, I received a tremendous amount of support from seed companies, seed dealers, processors and tomato growers. Second, I received invaluable assistance from the California Tomato Growers Association and from the Processing Tomato Advisory Board. Without the data supplied by these sources, the project would never have gotten off the ground. Third, I want to thank my adviser, Dr. Raymond Vlasin and the rest of my dissertation committee for their invaluable support and comments. Fourth, I want to thank my good friend Claudio Frumento who graciously spent many days working with me on the computer model and map. Fifth, I want to thank my wife's father, James Little for editing my dissertation. Finally, I want to thank the Kaplowitz family for being such great hosts during my frequent trips to Michigan.

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CHAPTER I

INTRODUCTION

I.1. Importance of Genetic Traits to Agricultural Production:

Between 1965 and 1995 California's share of total U.S. processing tomato production increased from slightly less than 56 percent to over 92 percent. In addition, California growers control nearly half of the worldwide production of processing tomatoes. Although California has been able to capture a large share of the market due to excellent soils and nearly ideal climatic conditions, the state's processing tomato industry also has been at the forefront of technological innovations. The innovations have significantly reduced production costs while causing yields to increase by more than 50 percent from 20.1 to 33.5 tons per acre.

During the early 1960s and early 1970s two mechanical innovations were largely responsible for increasing California's dominance of the processing tomato industry. These include the mechanical harvester and the electronic tomato sorter which significantly reduced labor costs while increasing harvesting efficiency. In more recent years, varietal improvements have dramatically improved yield and quality while also helping to reduce production costs. Since the introduction of hybrid varieties during the late 1970s, yields have increased between 5 and 10 tons per acre, while quality attributes such as soluble solids have markedly improved. In addition, hybrids sometimes enable plant breeders to reduce the amount of time needed to develop new varieties while enhancing breeding flexibility. This has led to

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the introduction of hundreds of new varieties with slightly different combinations of twenty to thirty important genetic characteristics.

Although hundreds of new varieties have been released over the past fifteen years, only a few have managed to capture a significant share of the market. The remainder each comprise less than 1 percent of the inspected loads. However, in most cases, the reign of even the most successful varieties seldom lasts for more than four or five years. Before long, new and improved varieties quickly take their place. During 1995, 208 varieties were graded by state inspection stations. The top twenty-five varieties comprised over 80 percent of the inspected loads, while the top five varieties comprised over 50 percent of the inspected loads. However, only one of the top five varieties inspected during 1995 was among the top five during 1991.

The primary reason why varieties are constantly replaced by new and improved varieties is the competitive nature of the processing tomato industry. A variety with slightly higher yield can mean the difference between a grower losing money or earning a profit. In addition, shifts in consumer demand and improved production efficiencies at competing canning facilities, have forced processors to constantly seek-out new varieties with slightly different sets of characteristics. For example, processors in recent years have increased their use of varieties that peel and dice well to satisfy the recent up-surge in salsa demand. Meanwhile, paste producers generally attempt to purchase varieties with high soluble solids to reduce their production costs.

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The decision of which varieties to adopt is hampered by the fact that growers and processors are oftentimes interested in somewhat different sets of characteristics. In addition, the selection of certain characteristics desired by growers can adversely affect the attributes desired by processors and vice versa.[1] For example, growers are primarily interested in characteristics such as yield, disease and nematode resistance and stress tolerance. Processors, on the other hand, are primarily interested in quality related characteristics such as color, viscosity and soluble solids.

Varietal choices are further hampered by a lack of information regarding differences in the package of characteristics contained within each variety. As a result, it is difficult for growers and processors to discern the differences among the varieties. It is also difficult for growers and processors to evaluate how well each variety will perform on large tracks of land in different regions since there is a wide range of weather, soil types and cultural practices across the state. Thus, both growers and processors are hesitant to switch to new varieties that are unproven or for which they have little information. However, according to Hiebert (1974), as decision makers obtain more information about particular varieties, their risk of making incorrect allocative decision is reduced and at the limit is eliminated. Assuming that attitudes towards risk are randomly distributed, then ceteris paribus, the probability that a randomly chosen firm will be an adopter increases as the stock of information improves.

[1] It is usually difficult to achieve both high yields and high soluble solids. As yields increase, soluble solids tend to fall and vice versa.

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I.2. Objectives:

The objective of the dissertation is to shed light on how California growers and processors select processing tomato varieties. This is accomplished by examining the relationships between grower profits per variety and load share, and between profitability and yield.[2] Intuitively, one would expect the most profitable varieties to have the largest load shares. In addition, since grower profitability and yield are highly correlated, one would expect the highest yielding varieties to have the largest load shares. However, due to numerous possible intervening factors, some of which were briefly discussed above, these relationships are not observed. Rather, it is hypothesized that there is virtually no correlation between grower profitability and load share. Consequently, yield and profitability play an insignificant role in variety selection. This occurs despite growers' claims that yield influences their variety choices more than any other characteristic.

The above result is supported by the finding that yield's estimated implicit prices at the regional and state levels are insignificant and hence do not influence seed prices. If yield affected variety selection, one would expect it to play a significant role in how seed companies set their seed prices. Other characteristics, which appear to have a minor impact on grower profitability, such as field holding, soluble solids and vine size, may play a greater role than yield in determining which varieties growers and processors select.

The observation that yield and profitability play an insignificant role in variety selection is important for several reasons. First, a considerable amount of time is

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[2] Load share is defined as the percentage of total annual production contributed by each variety.

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spent by the processing tomato industry to identify high yielding varieties. It may be more appropriate for the processing tomato industry to focus on other characteristics that compliment yield. Second, given the current glut of processing tomatoes available on the world market, growers might prefer varieties that reduce their production costs or that reduce the likelihood of the crop rotting in the field. Third, growers may realize that although yield has increased by over 10 tons per acre over the last thirty years, inflation adjusted profits have remained virtually unchanged. Thus, the long-run benefits growers' derive from adopting high yielding varieties is somewhat uncertain.

I.3. Description of the Research Approach:

During phase I of the research project, primary data were collected concerning the basic structure of the processing tomato industry, and how the industry makes decisions regarding the creation and selection of varieties. This involved over forty one-on-one interviews with plant breeders, processors, seed company representatives, farm advisors, seed dealers, and organizations that represent the interests of processing tomato growers and processors. Next, a questionnaire was sent to all of the state's processing tomato growers. The purpose of the questionnaire was to obtain detailed information concerning the use and selection of varieties and characteristics which supplemented the information obtained during the interviews.

During phase II of the project, secondary data concerning variety prices and characteristics were collected from numerous sources, including the Processing Tomato Advisory Board (PTAB), seed companies, farm advisers, seed dealers and

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others who are familiar with the industry. During phase III, the data collected during the earlier two phases were first used to estimate the average profitability of the top twenty-five varieties inspected each year between 1991 and 1995. The estimated profits were then compared against the load shares of the same varieties. This included estimating the correlation coefficients between profitability and load shares for the current year, and between lagged profitability and load shares for the current year. The correlation coefficients between yield and profitability were also computed. The data were then used to estimate the implicit prices (value) of important processing tomato characteristics included as part of varieties inspected by PTAB between 1992 and 1996. The results of the implicit price estimations were used to strengthen the finding that yield and profitability play a minor role in variety selections.

I.4. Theoretical Framework For Estimating Implicit Prices:

The values of seed characteristics deemed to be important to growers and processors were determined by estimating the marginal implicit prices of each characteristic using hedonic pricing techniques. According to hedonic theory, the variability in the value of a class of goods can be described by the unique package of characteristics each good contains. The variability results in a range of prices faced by both producers and consumers. The method describes a competitive equilibrium in a plane of several dimensions on which both buyers and sellers locate. Any location on the plane is represented by the vector of coordinates $\mathbf{z} = (z_1, z_2,\ldots,z_n)$ with z_i measuring the amount of the **ith** characteristic contained in each good. When distinct packages of characteristics are offered, a price $\mathbf{p(z)} = \mathbf{p}(z_1, z_2,\ldots,z_n)$ is defined at

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each point on the plane which guides both consumer and producer locational choices regarding packages of characteristics bought and sold. If the respective bid and offer functions of consumers and producers of each package of traits are tangent to each other, and with the gradient of the hedonic price function, buyers and sellers are in equilibrium. The marginal implicit price of a characteristic can then be found by differentiating the hedonic price function with respect to the characteristic in question. This gives the increase in expenditure on x that is required to obtain one more unit of z_1, other things being equal.

I.5. Study Organization:

Chapter II of the study describes the organization of the processing tomato industry and the role played by seed developers, seed dealers, growers and processors. Chapter III addresses some of the basic genetics of processing tomatoes and the sources of important characteristics. Chapter IV describes how growers and processors select varieties. Chapter V presents the methodology used to estimate variety profitability and hedonic prices. Chapter VI compares the estimated profitability of the top twenty-five varieties against the actual load shares for the same varieties. The chapter also presents the estimated implicit prices of important processing tomato characteristics. The final chapter (VII) summarizes the results of the study. An appendix includes a copy of the questionnaire which was used to survey growers.

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CHAPTER II

PROCESSING TOMATO INDUSTRY BACKGROUND

The purpose of chapter II is to provide an overview of the processing tomato industry. The first part of the chapter describes the production, harvested acreage, yield and total value of processing tomatoes produced in the U.S. and California. This is followed by background descriptions of California processing tomato growers, tomato processors and the interaction between growers and processors. The last part of the chapter describes the role of seed companies and seed dealers in the processing tomato industry.

II.1. Tomato Production in California:

II.1.1. Production, Acreage and Yield:

Between 1965 and 1995 the production of processing tomatoes in the U.S. increased by nearly three-fold from 4.4 to 11.2 million tons. This occurred because harvested acreage increased from 257 to 345 thousand acres while the yield per acre increased by over 13 tons due to the introduction of improved cultural practices and hybrid varieties which tend to have greater yield potential and stress tolerance than open pollinated (OP) varieties (Table 2.1).[1] At the same time, California's share of domestic production increased from 56 percent to slightly over 94 percent, the state's

[1] In reality, what the industry refers to as open pollinated varieties (OPs), are actually inbred lines. Since inbred lines are characterized by homozygosity, the genetic composition of the offspring are identical to each other and to the inbred line bred to produce the offspring. Hybrids are produced by crossing two different inbred lines which results in heterozygous offspring.

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Table 2.1. Acreage and Production of Processing Tomatoes in California and the U.S.

Year	Area Harvested			Production		
	Cal.	U.S.	Cal. Share	Cal.	U.S.	Cal. Share
	----------Acres---------		Percent	----------1000 Tons----------		Percent
1965	122,800	257,520	47.69	2,468.30	4,411.34	55.95
1966	162,500	299,830	54.20	3,136.20	4,662.27	67.27
1967	186,700	327,060	57.08	3,192.60	5,189.55	61.52
1968	231,300	370,550	62.42	4,903.60	6,967.60	70.38
1969	154,000	266,590	57.77	3,372.60	4,901.65	68.81
1970	141,300	245,090	57.65	3,362.95	5,058.95	66.48
1971	163,700	258,130	63.42	3,879.70	5,515.55	70.34
1972	178,900	265,020	67.50	4,526.15	5,803.70	77.99
1973	218,000	295,100	73.87	4,861.40	5,934.55	81.92
1974	249,900	337,700	74.00	5,847.65	7,019.85	83.30
1975	299,200	384,250	77.87	7,270.55	8,503.75	85.50
1976	233,800	308,960	75.67	5,066.45	6,471.75	78.29
1977	276,400	346,660	79.73	6,669.55	7,779.15	85.74
1978	231,900	295,560	78.46	5,289.65	6,367.70	83.07
1979	250,000	312,030	80.12	6,350.00	7,329.51	86.64
1980	208,300	263,030	79.19	5,540.78	6,210.59	89.22
1981	204,300	253,920	80.46	4,903.20	5,716.13	85.78
1982	232,000	295,300	78.56	6,148.00	7,298.99	84.23
1983	233,500	292,020	79.96	5,972.93	7,029.84	84.97
1984	239,700	291,870	82.13	6,591.75	7,681.16	85.82
1985	217,000	265,500	81.73	6,102.04	7,177.13	85.02
1986	210,400	252,330	83.38	6,480.32	7,398.47	87.59
1987	214,000	257,400	83.14	6,702.48	7,607.69	88.10
1988	226,100	274,920	82.24	6,547.86	7,409.92	88.37
1989	276,500	320,850	86.18	8,585.33	9,484.47	90.52
1990	310,000	354,700	87.40	9,306.20	10,355.26	89.87
1991	312,000	355,980	87.65	9,893.52	10,872.99	90.99
1992	240,000	273,810	87.65	7,932.00	8,776.47	90.38
1993	274,000	307,470	89.11	8,951.58	9,676.54	92.51
1994	311,000	340,060	91.45	10,748.16	11,542.31	93.12
1995	317,000	343,980	92.16	10,606.82	11,276.09	94.06

Sources: USDA, National Agricultural Statistics Service, Vegetables (Summaries for 1990-1995); USDA, Economic Research Service, U.S. Tomato Statistics, 1960-90, Statistical Bulletin No. 841, August, 1992.

share of harvested acreage increased from 47.7 percent to 92.2 percent and the average yield increased from 20.1 to 33.5 tons per acre (Table 2.2).

The shift of production and harvested acreage to California occurred for several reasons. First, California's growers have significantly reduced the amount of labor needed to produce each ton of processing tomatoes which has significantly reduced their production costs. Second, new tomato harvesters which were specifically designed for California's growing conditions and varieties, are much more efficient than the models introduced during the early 1960s.[2] Third, the risk of crop loss is significantly lower in California than in other growing regions since the state's growers generally have excellent and predictable weather conditions.[3] Fourth, most of the inefficient California growers have been forced out of business over the past thirty years. Fifth, California's agricultural infrastructure is much more developed than in competing growing regions both domestically and internationally [May--personal communication]. Sixth, California's processing plants are bigger and faster than plants built in other parts of the country and around the world [Hirahara--

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[2] One grower indicated that after adjusting for inflation, he is spending less per acre than 10 years ago because new harvesters are much more efficient, and because he spreads his fixed costs over more acreage. In addition, his incorporator, planter and harvester are doing more work and repair costs are increasing proportionately less. Since harvesters are much more efficient, custom harvesters have reduced their fees from $18 to only $11-$13 per ton [Herringer--personal communication]. The original Blackweller needed 20 people whereas modern harvesters only need 6 people [Merwin--personal communication].

[3] Dry areas with low humidity--similar to a Mediterranean climate--are best suited for growing tomatoes. Some of the best growing regions are found in California, Chile and certain areas within the Mediterranean [Stevens--personal communication]. The dry weather in California significantly reduces foliar diseases (mold) [Jacobs--personal communication] whereas tropical areas are disease prone [Rivara--personal communication].

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Table 2.2. Yield, Prices and Total Value of Processing Tomatoes Grown in California Deflated by the Consumer Price Index 1982-84=100 (all items), 1965-95

Year	Yield	Price per Ton		Total Value	
		Farm	Processor Door	Farm	Processor Door
	Tons	----------Dollars----------		----------1000 Dollars----------	
1965	20.1	112.38	132.06	277,389.9	325,972.3
1966	19.3	92.59	111.42	290,388.8	349,434.0
1967	17.1	115.87	134.43	369,921.0	429,184.8
1968	21.2	101.15	118.97	495,996.3	583,359.3
1969	21.9	74.11	91.28	249,958.3	307,853.1
1970	23.8	64.95	81.44	218,418.4	273,889.7
1971	23.7	69.14	83.95	268,226.1	325,703.2
1972	25.3	66.99	81.34	303,187.0	368,155.7
1973	22.3	78.13	91.74	379,796.8	445,990.0
1974	23.4	115.21	129.41	673,725.1	756,754.7
1975	24.3	103.35	116.17	751,380.2	844,627.0
1976	21.7	83.30	98.77	422,055.7	500,412.1
1977	24.1	92.57	105.45	617,428.6	703,274.3
1978	22.8	82.52	97.70	436,477.2	516,795.5
1979	25.4	78.10	92.98	495,929.7	590,392.5
1980	26.6	57.89	72.45	320,746.6	401,437.5
1981	24.0	55.89	71.18	274,018.2	348,995.6
1982	26.5	57.62	70.98	354,226.7	436,412.4
1983	25.6	53.92	65.96	322,034.4	393,997.4
1984	27.5	50.05	62.37	329,904.7	411,112.0
1985	28.1	47.77	59.57	291,491.5	363,513.7
1986	30.8	46.53	56.75	301,547.7	367,769.9
1987	31.3	40.85	50.35	273,763.2	337,484.0
1988	29.0	40.74	49.79	266,785.1	326,009.2
1989	31.3	44.76	55.08	384,262.7	472,885.5
1990	30.0	42.23	50.73	393,039.2	472,074.2
1991	31.7	38.84	47.50	384,263.7	469,978.5
1992	33.1	32.86	40.20	260,630.9	318,863.0
1993	32.7	33.43	40.90	299,211.9	366,116.5
1994	34.6	34.35	41.16	369,150.7	442,400.6
1995	33.5	33.79	41.60	358,404.4	441,243.7

Sources: USDA, National Agricultural Statistics Service, Vegetables (Summaries for 1990-1995); USDA, Economic Research Service, U.S. Tomato Statistics, 1960-90, Statistical Bulletin No. 841, August, 1992; USDA and California Agricultural Statistics Service, California Vegetable Review.

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personal communication]. Lastly, the average soluble solids obtained from tomatoes produced in California are 10 to 20 percent higher than the soluble solids obtained from other production regions which reduces processing costs [Tarry--personal communication].

II.1.2. Regional Production in California:

Ninety-two percent of the processing tomatoes produced in California are grown in two main production regions. The remaining 8 percent are grown in three minor production regions (Table 2.3). Region I, which produces approximately 56 percent of the state's processing tomatoes, is the northern most growing region and is centered in Yolo county (Figure 2.1). It includes most of the Sacramento Valley, the Sacramento-San Joaquin Delta and the San Joaquin Valley from Merced northward. Tomatoes are planted between February and mid-June and harvested between July and the first half of October. Region II produces approximately 35.6 percent of the state's processing tomatoes and includes the land planted in the San Joaquin Valley from Merced southward. Tomatoes are planted between late January and early April and are harvested between late June and mid-August. Region III produces approximately 3 percent of California's processing tomatoes and includes land planted in the state's central coastal valleys. Tomatoes are planted between March and April and harvested between August and mid-October. Two percent of the state's processing tomatoes are produced in Region IV, which consists of land planted in the southern coastal areas in Ventura and Orange counties. Tomatoes are planted between March and May and harvested between September and November. Region

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Table 2.3. California Processing Tomato Production by County and Region for Selected Years

Map Reference Number	County and Region	Production For Selected Years			
		1980	1985	1990	1995
		----------Thousand Tons----------			
	Region I:	3,442.2	3,114.8	4,425.0	6,005.1
1	Yolo	1,250.0	1,139.0	1,700.0	2,221.8
2	San Joaquin	706.9	618.0	660.0	904.4
3	Sacramento	233.4	104.9	160.0	181.5
4	Solano	354.4	299.9	500.0	580.8
5	Stanislaus	211.3	290.0	365.0	499.9
6	Colusa	162.1	285.0	600.0	939.0
7	Sutter	526.1	378.0	440.0	677.7
	Region II:	1,371.8	2,234.0	3,795.0	3,780.0
8	Merced	188.7	174.0	240.0	402.6
9	Fresno	1,058.0	1,896.0	3,300.0	3,377.4
10	Kern	125.1	129.0	165.0	-----
11	Kings	-----	35.0	90.0	-----
	Region III:	438.4	399.0	420.0	250.1
12	Contra Costa	116.3	155.0	130.0	138.3
13	Monterey	57.3	36.0	90.0	-----
14	San Benito	154.1	154.0	140.0	71.7
15	Santa Clara	110.7	54.0	60.0	40.1
	Region IV:				
16	Ventura	115.7	127.0	130.0	-----
	Region V:				
17	Imperial	-----	-----	330.0	-----
	Other Counties[a]	157.4	171.0	70.0	571.6
	State Total	5,540.8	6,102.0	9,306.0	10,606.8

Source: United States Department of Agriculture, California Agricultural Statistics Service, Sacramento, CA, California Vegetable Review (various issues between 1980-95).

[a] To avoid disclosure of individual operations, Other Counties includes: Madera, Monterey, Kern, Kings, Imperial, Santa Barbara, Tulare, and Ventura.

Figure 2.1. Location of California Processing Tomato Counties and Regions

V, which is in the far southern part of the state and includes the Imperial Valley, produces the remaining 3 percent of California's processing tomatoes. Desert land in this area is planted between January and March and harvested between May and July [U. of California, 1985].

Many of the older production areas are in Region I. Yolo and San Joaquin counties have historically produced the most tomatoes in the region. However, in recent years Colusa county also has become an important production region since it has a unique micro-climate which is well suited for tomato production. Fresno county, which is located in Region II, has been the dominant producing county for the past few years. Between 1980 and 1995, production in Fresno county more than tripled and now represents nearly one-third of the state's production. The distribution of harvested acreage more or less reflects regional and county production shares (Table 2.4), although the average yields per acre vary somewhat widely across the state (Table 2.5). During 1995, the average yield in Region I was 32.5 tons per acre while the average yield in Region II was 35.2 tons per acre. The yield difference is primarily due to the fact that Region II is almost exclusively an early season production area which reduces the likelihood of the plants suffering damage from diseases, moisture and environmental stress. In addition, until recently the region had been farmed less heavily, and consequently, it has fewer disease and nematode problems than farm land in Region I.

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Table 2.4. California Processing Tomato Acreage Harvested by County and Region for Selected Years

Map Reference Number	County and Region	Acreage Harvested For Selected Years			
		1980	1985	1990	1995
		----------Acres----------			
	Region I:	134,990	117,470	155,330	184,700
1	Yolo	51,880	42,700	59,000	68,200
2	San Joaquin	27,330	22,940	25,200	23,500
3	Sacramento	8,530	3,860	5,400	6,400
4	Solano	13,270	11,270	15,800	19,200
5	Stanislaus	7,250	11,000	13,500	17,400
6	Colusa	6,060	10,100	20,200	28,500
7	Sutter	20,670	15,600	16,200	21,500
	Region II:	46,500	72,660	118,800	107,600
8	Merced	6,750	6,970	8,500	9,600
9	Fresno	34,640	60,200	102,000	98,000
10	Kern	5,110	4,160	5,000	-----
11	Kings	-----	1,330	3,300	-----
	Region III:	16,070	14,210	14,100	7,200
12	Contra Costa	3,980	5,150	4,800	4,000
13	Monterey	1,890	1,330	2,800	-----
14	San Benito	5,990	5,580	4,600	2,100
15	Santa Clara	4,210	2,150	1,900	1,100
	Region IV:				
16	Ventura	4,600	4,750	4,300	-----
	Region V:				
17	Imperial	-----	-----	10,000	-----
	Other Counties[a]	5,640	5,910	2,500	17,500
	State Total	208,300	217,000	310,000	317,000

Source: United States Department of Agriculture, California Agricultural Statistics Service, Sacramento, CA, California Vegetable Review (various issues between 1980-95).

[a] To avoid disclosure of individual operations, Other Counties includes: Madera, Monterey, Kern, Kings, Imperial, Santa Barbara, Tulare, and Ventura.

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Table 2.5. California Processing Tomato Yield Per Acre by County and Region for Selected Years

Map Reference Number	County and Region	Yield Per Acre For Selected Years			
		1980	1985	1990	1995
		----------Tons----------			
	Region I:	25.5	26.5	28.4	32.5
1	Yolo	24.1	26.7	28.8	32.6
2	San Joaquin	25.9	26.9	26.2	38.5
3	Sacramento	27.4	27.2	29.6	28.4
4	Solano	26.7	26.6	31.7	30.3
5	Stanislaus	29.1	26.4	27.0	28.7
6	Colusa	26.7	28.2	29.7	33.0
7	Sutter	25.5	24.2	27.2	31.5
	Region II:	29.5	30.8	32.0	35.2
8	Merced	28.0	25.0	28.2	41.9
9	Fresno	30.5	31.5	32.4	34.5
10	Kern	24.5	31.0	33.0	-----
11	Kings	-----	26.3	27.3	-----
	Region III:	27.3	28.1	29.8	34.8
12	Contra Costa	29.2	30.1	27.1	34.6
13	Monterey	30.3	27.1	32.1	-----
14	San Benito	25.7	27.6	30.4	34.1
15	Santa Clara	26.3	25.1	31.6	36.5
	Region IV:				
16	Ventura	25.2	26.7	30.2	-----
	Region V:				
17	Imperial	-----	-----	33.0	-----
	Other Counties[a]	27.9	28.9	28.0	32.7
	State Total	26.6	28.1	30.0	33.5

Source: United States Department of Agriculture, California Agricultural Statistics Service, Sacramento, CA, California Vegetable Review (various issues between 1980-95).

[a] To avoid disclosure of individual operations, Other Counties includes: Madera, Monterey, Kern, Kings, Imperial, Santa Barbara, Tulare, and Ventura.

II.1.3. Value, Use and Demand for Processed Tomatoes:

The total value of all U.S. processed tomato product shipments, including manufactured and remanufactured products, was approximately $4.7 billion in 1990. Tomato concentrates, which includes catsup, sauces and paste equaled $3.8 billion followed by tomato juice ($348 million) and canned whole tomatoes ($547 million). Between 1967 and 1990 the value share of tomato concentrates represented by catsup fell from slightly over 40 percent to slightly less than 20 percent. At the same time, the value share of concentrated sauces (which includes puree and crushed tomatoes) increased from slightly over 40 percent to over 63 percent, while the value share of paste fell slightly from 19.9 percent to 16.7 percent. Meanwhile, the value share of all canned tomato products decreased from 17.1 percent to 11.6 percent, while the value share of tomato juice fell from 13.7 percent to only 7.3 percent [Sullivan, 1992].[4]

It is difficult to estimate the utilization of raw tomatoes since the industry no longer provides data needed for this purpose. However, it was possible to construct a fairly accurate picture of tomato utilization by transforming U.S. Department of Commerce Census data on tomato shipments into farm equivalent weight (Table 2.6). Although the production of whole canned tomatoes doubled between 1972 and 1992, the product's market share only increased from 9.9 percent to 12.1 percent. Tomato juice production remained fairly flat over the twenty year period and market share fell from 13.4 percent to only 8.9 percent. The market share for catsup also fell over the

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[4] Although some products represent a smaller share of total value than in past years, they have still increased in value albeit at a lower rate.

Table 2
Selected

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Table 2.6. Estimated Utilization of Processing Tomato Production in the United States for Selected Years

Commodity	Commodity Production For Selected Years[a]				
	1972	1977	1982	1987	1992
	1000 Tons (Farm Weight)				
Whole Canned Tomatoes	576.5 (9.9)[b]	684.4 (8.8)	612.2 (8.4)	827.0 (10.9)	1061.0 (12.1)
Tomato Juice	778.0 (13.4)	705.4 (9.1)	606.3 (8.3)	729.7 (9.6)	777.8 (8.9)
Tomato Sauces	1238.1 (21.3)	1378.0 (17.7)	2023.8 (27.7)	2839.5 (37.3)	3461.0 (39.4)
Tomato pulp and puree[c]	———	———	———	623.8 (8.2)	429.3 (4.9)
Catsup	1595.1 (27.5)	1370.3 (17.6)	1510.5 (20.7)	1448.2 (19.0)	1471.0 (16.8)
Paste[d]	1616.0 (27.8)	3641.1 (46.8)	2546.2 (34.9)	1139.5 (15.0)	1576.4 (18.0)
Total Production	5803.7	7779.2	7299.0	7607.7	8776.5

Sources: (1) Production data: USDA, Nat. Ag. Statistics Service, Agricultural Statistics, various years 1972-93; (2) Production and Shipments by tomato product: USDC, Census of Manufactures, Industry Series: Preserved Fruits and Vegetables, various years 1972-92; Sullivan, Glenn and Filipe Ravara, "Organization, Structure and Trade in the North American Tomato Processing Industry, Acta Horticulturae, v.277, 1990, p. 263-289; (3) Unit Conversion Tables: USDA, Economics, Statistics, and Cooperatives Service, Conversion Factors and Weights and Measures For Agricultural Commodities and Their Products, Stat. Bulletin No. 616, 1985; Brandt, Jon, and Ben C. French, An Analysis of Economic Relationships and Projected Adjustments in the U.S. Processing Tomato Industry, U. of Cal., Giannini Foundation Research Report No. 331, December 1981, p. 96-97.

[a] Each commodity was expressed in terms of the equivalent farm level weight. The amount of each commodity contained in 1000 24/303 cases was converted to farm weight (1000 tons) by multiplying each commodity by one of the following conversion factors: canned tomatoes (36.36 lbs), tomato juice (36.36 lbs), catsup (66.67 lbs), sauce (66.67 lbs), pulp and puree (80 lbs) which was then divided by 2000.

[b] The numbers in parentheses are the percentage shares of total production contributed by each commodity for a particular year.

[c] Pulp and puree were combined with sauces for 1972, 1977, and 1978 and a weighted average conversion to pounds was used (67.67 lbs).

[d] Paste utilization was derived by subtracting total utilization of all other tomato products (farm weight) from total production. The numbers estimated for paste vary significantly more than for the other commodities since paste is used to create sauces and catsup. If demand for these other commodities is satisfied the remaining production is sold or stored as paste.

same period from 27.5 percent to 16.8 percent. However, the market share for sauces (including pulp and puree) grew substantially over the same period from 21.1 percent in 1972 to 44.3 percent in 1992.

The demand for California's processing tomatoes has become much greater in recent years due to a significant increase in the demand for tomato products. The per capita domestic demand for tomato products has been growing between 2 and 4 percent annually for the past ten to twenty years [Storz, Pruett--personal communication]. The increased demand is partly due to lower prices associated with improved production efficiency [Storz--personal communication]. Between 1970 and 1995 the inflation adjusted prices of all processed tomato products declined by as much as 40 percent (Table 2.7). In real terms, canned tomato prices fell by 37 percent, juice prices fell by 30 percent, puree prices fell by 27 percent and paste prices fell by 40 percent.

However, most of the increased demand for processed tomatoes is due to a shift in consumer tastes and preferences and a dramatic increase in exports. Domestic consumers are eating far more pizza and other prepared foods than they did twenty years ago. This has stimulated the demand for sauces, while the demand for salsa which was practically non-existent several years ago, now exceeds the demand for catsup [Merwin--personal communication]. Salsa demand has been growing by 15 percent per year for the past five or six years [Pruett--personal communication]. California's growers also have been able to capture a larger share of the international market partly because the European Economic Community has reduced and/or eliminated many of the subsidies which were formerly paid to tomato growers in high

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Table 2.7. Season Average California F.O.B. Prices of Processed Tomato Products Deflated by the Consumer Price Index 1982-84=100 (all items), 1970-1995

Year	Processed Tomato Products				
	Canned Tomatoes Standard 24/303 Cases	Juice Fancy 12/46 oz. Cans	Catsup Fancy 24/12 oz. Glass	Puree (sp. gr. 106) 6/10 Cans	Paste (26 percent) 6/10 Cans
	----------Dollars Per Case----------				
1970	9.38	7.86	11.08	12.71	19.41
1971	9.38	7.73	10.84	13.31	20.96
1972	9.47	8.30	11.00	13.85	20.55
1973	9.55	8.62	10.47	15.07	24.53
1974	11.01	10.45	14.20	18.88	34.44
1975	9.83	8.98	13.74	15.33	25.33
1976	10.77	9.63	14.15	15.38	24.94
1977	9.54	8.40	11.12	13.00	22.82
1978	9.37	9.03	11.50	12.68	22.73
1979	8.32	8.06	10.47	10.72	19.75
1980	9.81	8.71	11.65	13.31	21.67
1981	10.51	9.39	11.88	15.60	25.12
1982	8.42	8.08	11.92	14.63	24.68
1983	7.79	8.21	11.55	13.64	23.68
1984	7.37	7.47	11.07	11.19	18.29
1985	7.04	7.13	-----	10.49	16.34
1986	7.35	7.13	9.40	10.01	16.02
1987	7.48	7.04	9.07	9.90	16.07
1988	7.19	6.76	8.71	10.00	16.06
1989	7.06	6.85	-----	11.49	20.16
1990	6.69	6.50	-----	10.02	17.98
1991	6.52	6.24	-----	8.78	15.79
1992	6.41	6.06	-----	7.75	14.97
1993	6.23	5.88	-----	7.37	11.42
1994	6.07	5.74	-----	7.93	11.81
1995	5.91	5.58	-----	8.04	11.81

Sources: Pacific Fruit News (various issues); The Almanac of the Canning Freezing, Preserving and Allied Industries (various issues), Edward E. Judge & Sons, Inc., Westminster, MD; Jon A. Brandt and Ben C. French, An Analysis of Economic Relationships and Projected Adjustments in the U.S. Processing Tomato Industry, U. of Cal., Giannini Foundation Research Report No. 331, December, 1981.

cost producing countries like Italy [Stevens--personal communication]. In addition, the importation of tomato products into the U.S. has fallen due to lower domestic prices. As a result, during 1995 the U.S. achieved net exports of 339 thousand pounds of a wide assortment of tomato products. In comparison, during 1985 the U.S. had net imports of 300 thousand pounds of tomato products (Table 2.8).

II.2. Relationship Between Growers and Processors:

II.2.1. Background of California Processing Tomato Growers:

Growers choose to grow tomatoes for a variety of reasons. First, they are familiar with the industry. Second, the crop fits in well with their crop rotation. Third, in some areas there are no other crops that are more profitable. Fourth, if a grower stopped producing tomatoes for one year, it may be difficult for him to secure new contracts the following year [Fawcett, Pruett--personal communications]. Fifth, most growers have made sizable investments in the machinery needed to grow tomatoes. The harvester, which costs close to $250 thousand, and other equipment such as incorporators, are expensive and can only be used for tomato production.[5]

However, the number of processing tomato growers in California has been steadily declining while the average farm size has been increasing. Collins, Mueller, and Birch (1956), reported in 1956 that processing tomato farms in northern

[5] The cost of purchasing a new harvester has increased considerably since they were first introduced during the early 1960s when they cost only $18 thousand [Robertson--personal communication].

Table 2.8. U.S. Imports and Exports of Processed Tomato Products for Selected Years

Period	Pulp and Puree	Paste	Sauce[a]	Juice	Catsup and Chili	Whole and/or Other[b]
	----------1000 Pounds (Retail Weight)----------					
Imports						
1985	-----	111,400	33,586	-----	-----	220,028
1986	-----	130,625	31,590	-----	-----	197,559
1987	-----	101,274	17,201	-----	-----	178,587
1988	-----	107,655	10,761	-----	-----	175,528
1989	-----	228,400	24,221	-----	-----	111,590
1990	-----	136,913	19,072	-----	-----	137,292
1991	-----	94,954	18,412	-----	-----	107,471
1992	-----	43,759	15,382	-----	-----	95,495
1993	-----	62,100	15,465	-----	-----	91,994
1994	-----	95,249	44,822	-----	-----	99,648
1995	-----	52,386	39,744	-----	-----	131,866
Exports						
1985	1,398	15,691	4,753	11,984	18,082	15,939
1986	811	17,234	6,187	15,000	18,902	13,902
1987	2,506	20,440	6,479	13,272	23,450	8,040
1988	4,752	26,618	16,662	18,689	26,447	11,842
1989	11,233	30,302	58,781	13,033	25,782	9,124
1990	6,988	84,724	53,883	14,857	31,535	14,189
1991	10,451	97,257	79,146	20,557	38,007	20,171
1992	14,271	161,294	132,078	25,796	53,995	30,974
1993	19,884	171,301	138,449	27,264	52,270	55,265
1994	12,940	172,141	170,771	37,357	82,031	42,662
1995	14,573	199,970	155,233	46,855	87,427	59,195

Source: U.S. Department of Commerce, Bureau of Census.

[a] In the case of imports tomato-based sauces containing additional seasonings are not included prior to 1989.

[b] For the most part this category consists of whole tomatoes. However, exports contain other tomato products in addition to whole tomatoes except for 1989-91 during which time the category only included whole tomatoes.

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California averaged 91.1 acres. In 1975, 845 California growers produced 305,600 acres of processing tomatoes on farms that averaged of 361.7 acres [Brandt et al., 1978]. In 1995, approximately 450 growers farmed 317,000 acres on farms that averaged 704.44 acres in size [Durham, 1995 and Welty--personal communication].[6]

There are several possible reasons why the consolidation of farms has taken place. First, since it is very expensive to purchase and maintain tomato growing equipment, only large growers are able to purchase the needed equipment [Woolf--personal communication]. Second, modern harvesters can handle one-third more acreage than the machines built several years ago [Remonda--personal communication]. Thus, growers have expanded their farms to spread the fixed cost of their machinery over more acreage. In many cases, the only way a grower can expand is by purchasing his neighbor's land [Cooley--personal communication].

The number of growers also has fallen since many of them purchased additional land when land and agricultural prices were high during the early 1980s. Several years later, they were forced to sell at a loss when the price of agricultural products fell [Hirahara--personal communication]. Many growers expanded their farms to preempt rural development and other growers who were quickly purchasing the available land. When agricultural prices unexpectedly fell, they found themselves only earning $200 per acre before subtracting the land payment [Yerxa--personal communication]. In addition, when the price of the land fell, they suddenly had less

[6] Based on the results of a 1995 mail survey of California processing tomato growers, the average size of the respondents tomato operations was 866.1 acres.

collateral to obtain loans to purchase needed farm inputs.[7] At the same time, growers suffered some of the worst weather related crop disasters on record due to heavy rains and high temperatures [Herringer--personal communication]. Finally, some growers were forced out of business because they were unable to produce high quality tomatoes and were not offered new contracts [May--personal communication].

The remaining growers have survived the ups and downs of the industry by becoming more efficient. Growers who failed to become more efficient were forced out of business since the price growers receive per ton has been falling faster than yields have been increasing. The price growers received fell from an inflation adjusted price of $112 per ton in 1965 to only $34 per ton during 1995. At the same time, yields increased from 20.1 tons to 33.5 tons per acre (see Table 2.2). Thus, total inflation adjusted revenues during 1965 equaled $2259. In comparison, revenues during 1995 equaled only $1132. If the average yield during 1995 had equaled 66.84 tons per acre, growers would have realized the same inflation adjusted revenue they earned during 1965.

Growers have been able to compensate for the lost revenue by becoming more efficient. After adjusting for inflation, growers' per acre average production costs fell from $2144 in 1965 to $1,282 during 1989. Thus, the average grower earned inflation adjusted per acre profits of $115 during 1965, and $119 during 1989 (Table 2.9--also see Table 2.2). As a result, growers' inflation adjusted profits have changed

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[7] Approximately twelve years ago, many growers purchased land at close to $4000 per acre. When the price of land fell to only $2000 per acre, growers suddenly found themselves with far less equity [Remonda--personal communication]. As a result, they were unable to secure large enough bank loans to purchase their inputs. Since they were unable to cover the cost of the high priced land, they were forced to sell all or part of their farms [Timothy--personal communication].

Table 2.9. Samp
by the Producer
Selected Years

Activity
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Planting
a. Seed Cost[a]
Growing Costs
Miscellaneous op growing costs
Total pre-harvest
Pre-harvest Costs
Harvest Costs[c]
Total growing an
Investment Costs
Total all Costs
Total Cost per T

Sources: California
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[a] The cost of
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acreage would app

[b] Pre-harvest
from 1975-76 to

[c] Harvesting
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required per acre d

Table 2.9. Sample Cost of Producing Processing Tomatoes in Yolo County, California Deflated by the Producer Price Index (1982=100) (Intermediate materials, supplies and components), Selected Years

Activity	Cost of Production for Selected Years			
	1965	1975	1982	1989
	----------Dollars----------			
Seed Bed preparation	133.49	73.87	91.79	122.26
Planting	55.03	76.44	141.41	126.35
(a) Seed Cost[a]	36.06	31.03	62.25	78.87
Growing Costs	322.17	334.99	344.91	327.02
Miscellaneous operating and growing costs	303.77	250.48	94.70	170.74
Total pre-harvest costs	814.45	735.79	672.81	746.35
Pre-harvest Costs per Ton[b]	40.74	28.29	28.03	26.65
Harvest Costs[c]	1,101.75	595.62	207.62	226.94
Total growing and harvesting costs	1,916.21	1,331.41	880.43	973.29
Investment Costs	227.81	494.99	401.93	308.37
Total all Costs	2,144.02	1,826.41	1,282.36	1,281.66
Total Cost per Ton	107.21	70.24	53.43	45.77

Sources: California Agricultural Extension Service, Tomato Costs 1965 Hand Harvest: Yolo County; California Agricultural Extension Service, Sample Cost of Production 1975:Yolo County; U.C. Cooperative Extension, Sample Cost of Production (1982 and 1989): Woodland Area.

[a] The cost of seed varies depending on whether open pollinated (OP) or hybrid seed is used or some combination. In 1965, the budget assumed that .75 lbs. of OP seed would be applied. In 1975, it was assumed that 1 lb. of OP seed would be applied. In 1982, 40 percent of the acreage was assumed to use .5 lbs. of hybrid seed and 60 percent 1.75 lbs. of OP seed. In 1989, it was assumed that 2/3 of the acreage would apply .5 lbs. of hybrid seed and the remainder would be planted with 1 lb. of OP seed.

[b] Pre-harvest and total cost per ton are based on the following estimated yields per acre: 1965 (20 tons), 1975 (26 tons), 1982 (24 tons), 1989 (28 tons).

[c] Harvesting labor costs fell dramatically between 1965 and 1982 due to the introduction of the mechanical harvester and the electronic tomato sorter. By 1982, 90 percent of the 135 hours of hired labor required per acre during 1965 had been eliminated.

very little over the past thirty years, despite the introduction of new technology such as the harvester, sorter and improved varieties. However, growers who are early adopters of technology may earn short-term profits that exceed the long-term equilibrium.

II.2.2. Background of California Tomato Processors:

During 1995, twenty-three companies operated a total of forty processing plants in California that turn raw tomatoes into a variety of intermediate and final products (Table 2.10). Twenty-seven of the forty processing plants are designed to produce a wide range of tomato products including paste, whole canned tomatoes, sliced and diced tomatoes and other products. The remaining thirteen plants are only designed to produce paste. For several reasons, most of the plants are located in Region I. First, Region I produces the majority of raw processing tomatoes. Second, transportation costs, which are borne by the processing companies, can be prohibitively expensive if tomatoes are shipped a long distance. Third, it is very expensive to build new processing plants (between $30 and $50 million). This has limited the movement of plants to Region II, although in recent years it has become an important source of raw tomatoes.

The industry is able to process slightly over 1 million tons of raw tomatoes each week. During the eight to ten peak processing weeks, most of the plants are run at close to capacity. The weekly capacity of each company varies widely from a high of 120 thousand tons for Beatrice/Hunt-Wesson, to a low of only ten thousand tons for Escalon Packers.

Table 2.10. California Processing Tomato Plant Number, Product Types, and Weekly Capacity During 1995

Firm Name	Number of Plants	Diverse Plants[a]	Paste Plants	Region	Weekly Capacity (000 tons)
American Home Food Products	1	1		I	28.0
Atwater Canning Co.	1	1		II	16.0
Beatrice/Hunt-Wesson	4	4		I	120.0
Campbell Soup Co.[b]	4	2	2	I	80.0
Colusa County Canning Co.	1		1	I	17.5
Contadina Foods, Inc.	2	1	1	I	60.0
Del Monte Corporation	1	1		I	28.0
Escalon Packers	1	1		I	10.0
Gangi Brothers Packing	1	1		III	13.5
Gilroy Canning Co.	1	1		III	13.5
Heinz U.S.A.	2	1	1	I	70.0
Ingomar Packing Co.	1		1	II	40.0
Los Gatos Packing Co.	1		1	II	30.0
Pacific Coast Producers	2	2		I	32.5
Quality Assured Packing	1	1		I	11.5
San Benito Foods	1	1		III	13.5
S-K Foods, Inc.	1		1	I	17.0
Stanislaus Food Products	1	1		I	45.0
Sun Garden Packing Co.	1	1		III	26.0
The Morning Star Packing Co.[c]	3		3	I/II	110.0
TOMA-TEK, Inc.	1		1	II	24.0
Tri/Valley Growers	6	5	1	I/II	110.0
Van den Bergh Foods Co.	2	2		I/II	95.0
Unassigned Capacity					9.0
State Total	40	27	13		1020.0

Sources: Catherine A. Durham, Richard J. Sexton and Joo Ho Song, Transportation and Marketing Efficiency in the California Processing Tomato Industry, Cal. Ag. Experiment Station, Giannini Foundation Research Report No. 343, 1995; Chris Rufer (personal communication 3/14/96).

[a] A plant is considered to be diverse if remanufacturing occurs locally and paste if remanufacturing occurs at a remote site.

[b] Includes Dixon Canning Co. and Valley Tomato Products, Inc.

[c] Includes Harter Packing Co. which is leased by The Morning Star Packing Co.

II.2.3. Interaction Between Growers and Processors:

Each year processors and the majority of growers negotiate the base price to be paid per ton of raw tomatoes, the number of tons to be delivered, incentives to be paid for certain desirable characteristics, and deductions from the net-paid weight due to inadequate color, soluble solids, high limited-use and other deficiencies. The contracts also usually include a list of approved varieties that growers are permitted to grow. The contracts are negotiated between the California Tomato Growers Association (CTGA), which is a bargaining cooperative representing approximately two-thirds of the California growers, and approximately twenty-two individual processors.[8]

Some industry members have argued that in many ways contracts are heavily biased in favor of processors. First, processors can terminate the contracts of growers and easily replace them with other growers. This places growers in a weak bargaining position since only slightly more than half of the growers belong to CTGA [Kennedy--personal communication].[9] As a result, non-members are free to contract for a lower price which tends to depress the price for all growers. Second, processors are able to purchase more tomatoes if demand warrants, while the contract allows them to cut off growers once their contracts have been satisfied--no matter how many tomatoes in excess of the contract are left in their fields [Hirahara--personal

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[8] Growers pay CTGA fifteen cents per ton to negotiate prices for them and to perform other tasks. Since over 10 million tons have been harvested the past few years, CTGA annually collects over $900 thousand in membership fees (assuming that 60 percent of all growers belong to the CTGA).

[9] Usually in October-November processors sit down and decide what they want as far as the finished product is concerned, and what varieties will get them the finished product. They then set-up all of the grower plans and decide which growers will be offered a contract [Kennedy--personal communication].

communication]. Third, the price per ton that growers receive from processors in real terms has declined precipitously over the past fifteen years. Growers have been able to remain profitable by producing more tons per acre while reducing their costs. Fourth, if processors are having machinery problems, or if they are running at capacity, growers are forced to hold their production in the field or seek out other buyers since processors in those situations are unwilling to accept the loads.[10] This creates an incentive for growers to plant varieties that have superior field holding. In contrast, if growers have production difficulties, processors are free to purchase tomatoes from other growers.[11] Fifth, growers do not capture the full value of their tomatoes since the contracted base price is not entirely based on content. For example, none of the processors pay extra for varieties that stem well or have high viscosity. In addition, while they are assessed deductions for poor color, only a few of the processors, such as Tri-Valley, provide a small incentive for above average color [Storz--personal communication].

II.2.4. Contracted Base Price:

The base price reduces growers' risk and uncertainty by eliminating wild price swings. It also enables growers to plan their input purchases without having to worry

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[10] Although the contract obligates the processor to purchase the number of tons stipulated in the contract, the grower is in a weak bargaining position if for some reason the processor is unable or unwilling to accept a portion of the contracted loads. For example, if a grower has a 10,000 ton contract with a processor which is unable to take more than 9500 tons, the grower will usually not contest the load reduction since the demand for tomato contracts exceeds the supply [Stewart and Storz--personal communication].

[11] Canneries will generally take excess production if the variety is on their approved list [Kuehn--personal communication].

about a sudden drop in the output price [Robertson--personal communication]. Efficient processors also may prefer price stability since they are able to compete in an environment where raw product costs are more or less identical. It also forces processors to be cautious about the number of tons they process since over-production causes the output price to fall, while the cost of the raw tomatoes remains the same [Kennedy--personal communication].[12] Unlike growers, who contract for a fixed base price, the price received by processors depends on prevailing supply and demand conditions [Pruett--personal communication].

The contracted base price depends on the number of planted acres, carry-in from the previous season, seasonal weather patterns, and the incidence of diseases and other problems that affect annual production. For example, during 1990, drought conditions reduced yields and carry-over stocks to very low levels. As a result, during 1991, CTGA was able to negotiate one of the best grower prices in several years ($55 per ton). Growers responded to the high price by planting additional acreage. In addition, since weather conditions were optimal, yields during 1991 were far above average. As a result, tomato production soared to approximately 9.9 million tons which caused inventories to greatly exceed processor needs. Subsequently, the price of bulk paste fell from fifty-five cents to only twenty-eight cents per pound. Processors experienced cash-flow problems and several of the less

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[12] In recent years, there have been discussions concerning the possibility of signing contracts several years in advance to enhance industry stability. For example, if production is very low one year, processors would deplete their warehouse stocks. Without a long term contract, the following year price would reach an equilibrium far above the market average. Additional acreage would be planted and new growers would enter the business. This would result in excess supply and lower grower prices [Merwin--personal communication].

efficient canneries went out of business. To correct the problem, processors during 1992 intentionally cut back on the number of days they operated their plants to reduce inventories. As a result, total raw tomato production fell to 7.9 million tons while the contracted grower price fell to $46 per ton [Pruett--personal communication].

II.2.5. Impact of Incentives and Deductions on the Base Price:

Although each processor must have an overall average price across purchased loads that is approximately equal to the target base price, processors are free to decide how to reach the target via differences in the incentives and deductions specified in the grower contracts.[13] Some processors offer growers incentives for early and late production, while others pay growers an incentive if the soluble solids exceeds a negotiated base level. The contracted price also has many built in deductions if the load of tomatoes fails to meet certain quality standards applicable to soluble solids, fruit color, mold, limited-use and several other quality parameters.[14]

For example, one processor may decide to reach the target base price by offering a $49 initial payment and soluble solids incentives. A second processor may offer a $49 initial payment with incentives for low material other than tomatoes (MOT) and low limited-use. A third processor may offer an early season premium and a soluble solids premium for loads delivered during the middle of the season.

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[13] CTGA allows some slight deviations in the base price from one processor to the next. The deviations are usually no more than $1.50 to $2.00 per ton [Tarry--personal communication]. Heinz claims that since its varieties yield much more than the majority of varieties on the market, it should be allowed to set a lower base price [Miyao--personal communication].

[14] Incentives and deductions can have a tremendous impact on the profits earned by each grower. For example, if a grower with 5000 acres of tomatoes is paid an incentive of $3 per ton and he harvests 30 tons per acre, he will earn an additional $450 thousand [Brown--personal communication].

Finally, a fourth processor may decide to attach a different pay scale to each variety delivered. Regardless of the strategy processors employ to reach the base price, it is very important that they select suitable varieties. For example, Colusa County Canning Co. uses historical harvest data to structure its variety list and incentive program. It knows from previous harvest data that if it contracts with certain growers who plant specific varieties, there will be a 3 percent loss due to defects such as mold, while the soluble solids will average 5.2 percent [Kennedy--personal communication].

Limited-use and mold are the major deduction categories followed by several other categories including material other than tomato (MOT). The soluble solids deduction was created to prevent growers from pumping their fruit full of water just before they are sent to be graded [Nichols--personal communication].[15] The color deduction is based on the comminuted color reading which is measured with an agtron-colorimeter. The higher the comminuted color reading, the worse the color of the fruit. If the reading exceeds thirty-nine, the load is rejected [Collis--personal communication]. Processors only pay a small nominal amount for badly damaged tomatoes which are referred to as "limited-use." Most canneries accept tomato loads which have between 3 and 5 percent limited-use without penalizing the grower. Above 5 percent, the deductions increase sharply. In some cases, hot weather has

[15] Soluble solids are measured using a refractometer. The soluble solids test measures the percentage of solids that are dissolved in solution in the blended tomato product. The primary dissolved solid is sugar. Thus, processors are able to calculate the sugar content from the soluble solids reading [Collis--personal communication].

resulted in limited-use deductions as high as 18 percent [Brown--personal communication].

There are several other ways that deductions can increase. First, deductions tend to increase during the latter part of the harvesting season due to mold associated with heavy rain and dew [Collis--personal communication]. Second, deductions increase on loads that are harvested during the latter part of the day since they have been exposed to slightly more heat, cool weather, diseases and other negative factors [Timothy--personal communication]. Third, deductions, particularly limited-use, tend to increase sharply the farther the fruit must be transported to reach an inspection station since some are crushed along the way and are exposed to the elements [Fabbri--personal communication]. For example, one grower indicated that limited-use increased by 5 percent when his tomatoes were transported from Fresno county to San Joaquin county [Woolf--personal communication].

If deductions in any deduction category are extremely high, the load will be rejected by PTAB.[16] In a typical year, 1 percent or fewer of the loads are rejected. However, growers frequently mix the rejected loads with other loads and resubmit them. In addition, the number of loads rejected by PTAB may be somewhat different than the loads rejected by processors. For example, during an extremely wet year processors may lower the rejection criteria to maintain quality [Collis--personal communication].

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[16] The state inspection stations allow a maximum of 2 percent for worms, 4 percent for green tomatoes, 3 percent for MOT, the comminuted color reading must be thirty-nine or lower and the mold content must be 8 percent or less (by weight). There is no limit for limited use [Kennedy--personal communication].

During the 1995 season, growers were paid incentives as high as $10 per net ton for varieties harvested after September 24, and $3 per net ton for varieties harvested before July 15 (Table 2.11). If the limited-use level was 1 percent or less, growers were paid an incentive between $2.50 and $3.00 per net ton depending on the processor. The incentives for limited-use gradually diminished as the percentage of limited-use increased. After the limited-use level exceeded 5 percent, a variable percentage was deducted from the base price. If the percentage of limited-use ranged between 5.5 and 8 percent, growers were paid the base price minus 1.5 times the percentage of limited-use above 5 percent. The incentives paid for soluble solids were the most variable among the processors. For loads with a soluble solids level of 5 percent or lower, one processor deducted $.50 from the base price paid per ton, while other processors paid an incentive as high as $1.75. When the soluble solids exceeded 6.2 percent, growers were paid an incentive ranging between $1 and $9, depending on the processor.

II.2.6. Role of Grading:

Processors base their incentives and deductions on the results of random tests performed on each load of tomatoes by grading stations located across the tomato growing regions. There are forty tomato grading stations in California which are operated during the harvest season by a quasi-state organization called the Processing Tomato Advisory Board (PTAB). Approximately 80 percent of the stations are shared by processors while the rest are used by only one processor [Pruett--personal

Table 2.11. Examples of Premiums and Deductions Included as Part of Negotiated Prices Between Growers and Processors During the 1995 Growing Season

Quality and Premium Payments		Deduction Standards[a]	
Type of Premium Payment	Dollars per Net Ton	Type of Deduction	Amount of Deduction
Late Season:		**Grass Green:**	
Sept. 10-16	5.00	2.0% or less	Actual % of mold
Sept. 17-23	7.50	2.5% and above	2x% grass green
Sept. 24-after	10.00	2.5%-4.0%	2x% grass green
Early Season:		**Mold:**	Actual % of mold
On or before July 15	3.00		
Master Acid:		**Worms:**	Actual % of damage
23.0 and below	1.00		
Limited Use:		**Limited Use:**	
1% or less	2.50-3.00	5.5%-8.0%	% above 5%
1.5%-2.0%	1.40-2.00	8.5%-14.0%	1.5x% above 5%
2.5%-3.0%	0.50-1.00	8.5%-11.0%	1.5x% above 5%
3.5%-4.0%	0.50-0.75	11.5% and above	2.0x% above 5%
4.5%-5.0%	0.25-0.50	14.5% and above	2.0x% above 5%
Comminuted Color Reading:			
23 and below	1.30		
Material Other than Tomato (MOT):		**Material Other than Tomato (MOT):**	
0.0%	0.75-1.50	0.5% or less	1x% of MOT
0.5%	0.50-0.75	above 0.5%	3x% of MOT
Soluble Solids:		**Soluble Solids:**	
5.0	0.00-1.75	5.0	($.50)
5.4	0.00-2.75		
5.8	1.00-7.20		
6.2	1.00-9.00		

Source: California Tomato Growers Association, Inc. 1995 Negotiated Prices.

[a] Loads are rejected if mold is in excess of 5%, grass green is in excess of 4%, the MOT is in excess of 3% of gross weight and the Agtron color reading is in excess of the level established by the Director of Food and Agriculture.

communication].[17] The inspections provide an accurate description of the harvest and establish the legal description of the load which is needed to calculate the net paid weight.[18] During 1995, the stations inspected over 400 thousand loads and recorded data on over 200 different varieties.[19] Inspections start in the Imperial Valley in June, and spread northward day and night through the Central Valley in mid-summer and end in the cooler valleys in mid-October [Collis--personal communication].[20]

The grading stations take samples of each load to estimate the percentage of defects caused by broken fruit, mold, sunburn and other physiological disorders. Each load is permitted to have a low level of defects without suffering deductions.[21] However, once this level is exceeded, the deductions become progressively larger. If the deductions become too large, the entire load is rejected. The stations also measure fruit color and soluble solids. Processors use the information on color and

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[17] However, the methods used by the inspection stations are the same since they are all staffed and run by PTAB. Consequently, each station uses virtually identical inspection techniques and equipment. Some equipment that is used for unique testing and other aspects of the stations are tailored to meet the particular needs of the individual processors [Collis, Kennedy, Rufer--personal communication].

[18] The net paid weight equals the number of tons a grower is paid for per load after weight based deductions are taken. Incentives are paid on the tons that remain after the deductions are taken. For example, suppose that a grower submits a load that weighs 22 tons and that one ton is deducted due to high mold. Next, suppose that the grower is paid a $2 bonus per ton for high soluble solids. If the base price is $51.50, the grower is paid $53.50 on the 21 tons that remain [Rufer--personal communication].

[19] During 1995, PTAB inspected over 425 thousand loads of tomatoes. Each load weighed approximately 24.9 tons.

[20] The information is recorded by county and is then aggregated at the state level.

[21] For example, the allowable worm percentage is two percent, allowable mold content is 8 percent and green tomatoes can be as high as 4 percent [Collis--personal communication].

soluble solids to take additional deductions or to calculate grower quality incentives.[22] They also use the data to compare the yield and quality of different varieties grown both regionally and state-wide and the performance of each grower.[23] This enables them to add or subtract varieties from their approved variety list and to decide which growers to offer a contract to the following year. Growers use PTAB data to determine how well their varieties performed, and to select approved varieties for the next planting [May--personal communication].

II.3. Seed Companies and Seed Dealers:

II.3.1. Background of Seed Companies:

Between 1991 and 1995, nineteen seed companies produced and sold processing tomato seed in California. Some of the companies had a large number of varieties inspected by PTAB, while other seed companies had very few inspected varieties. For example, thirty-nine Petoseed Company varieties were inspected by PTAB during 1995, while four of the seed companies contributed only one inspected variety, and two of the companies contributed no inspected varieties. For many of the seed companies, the share of inspected varieties deviated only slightly from year to year. However, the number of inspected varieties sold by GSN Seed Co. fell from

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[22] Although viscosity is very important to processors, it is not measured by the inspection stations since the procedure is expensive and time consuming. Viscosity is expressed in terms of bostwick. The lower the bostwick number the higher the viscosity. Bostwick is measured by placing paste in a trough. As the paste moves along the trough, processors measure the number of centimeters it travels in 30 seconds [Kuehn, Rufer--personal communication].

[23] Most processors provide their growers with a report card at the conclusion of the season which enables growers to see how well they performed relative to other growers. Heinz has a report card which ranks each grower from one to fifty for each of the attributes they consider to be important. Heinz distributes a list of the rankings to all of its growers [Pruett--personal communication].

twenty-three during 1991, to only four during 1995. At the same time, the number of inspected Van den Bergh varieties increased from zero during 1991, to thirteen during 1995 (Table 2.12).

Although Petoseed Company sold the largest number of varieties inspected during 1995, its varieties did not control the largest share of inspected tomato loads. Of the ten seed companies that contributed twelve or more inspected varieties during 1995, only five of the seed companies controlled a significant share of the inspected loads. Heinz controlled the largest share (32.3 percent) followed by Orsetti Seed Company (25.7 percent), Asgrow (8.93 percent), Petoseed (8.63 percent) and Ferry Morse (5.81 percent) (Table 2.13). Part of the reason why Heinz and Orsetti varieties are so popular, is because they perform well on some of the key quality tests given during inspection. For example, during 1995, Orsetti varieties ranked fourth best overall for mold, third for color and second for limited-use. Heinz varieties were fifth for color and first for limited-use (Table 2.14).

However, successful seed companies can ill afford to rest on their laurels. Market load shares fluctuate considerably from year to year due to the introduction of new and improved varieties and changes in consumer tastes and preferences. This is illustrated by the change in the share of inspected loads experienced by the leading seed companies over the past five years. The market shares of Asgrow, Ferry Morse and Petoseed fell by 26, 76 and 62 percent respectively, while the market shares of Heinz and Orsetti increased by 396 and 720 percent respectively. As a result of the competition, some seed companies have sold-out to competitors or have gone out of business. Hunts eliminated its plant breeding division overnight once the company

Table 2.12. Number of Processing Tomato Varieties Inspected Between 1991-95, by Seed Company

Seed Companies	Number of Varieties				
	1991	1992	1993	1994	1995
Asgrow	14	13	17	20	17
Campbell	6	9	12	13	15
Del Monte	2	-----	3	1	1
Derutter	-----	-----	-----	-----	1
Eclipse[1]	6	4	8	10	7
Ferry Morse	18	18	20	20	18
GSN[2]	23	6	8	4	4
Harris Moran	11	11	17	16	12
Heinz	25	26	21	29	31
Hunts	5	5	4	7	6
Ochoa	-----	-----	-----	1	1
Ohio State	3	2	1	1	1
Orsetti	7	10	10	11	13
Peto[3]	37	35	27	37	39
Rogers NK	9	11	16	14	12
Sunrise	2	1	-----	1	-----
Sunseeds[4]	24	13	14	16	14
United Genetics	-----	-----	1	-----	-----
Van den Bergh	-----	-----	-----	10	13
Unknown	14	16	7	9	2

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1991-1995.

[1] Includes varieties that were formerly sold by Seeds of Tomorrow, and Plant Genetics, Inc. (PGI).

[2] Includes varieties that were formerly sold by Goldsmith Seeds, Newman Seeds and Northrup King.

[3] Includes varieties that were formerly sold by Royal Sluis.

[4] Includes varieties that were formerly sold by Castle and ARCO.

Table 2.13. Market Share of Processing Tomato Loads Inspected Between 1991-95, by Seed Company

Seed Companies	Market Share of Total Loads				
	1991	1992	1993	1994	1995
	----------Percent----------				
Asgrow	12.00	14.20	13.80	13.41	8.93
Campbell	5.75	4.48	3.42	5.01	5.35
Delmonte	0.07	-----	0.02	0.00	0.00
Derutter	-----	-----	-----	-----	0.01
Eclipse	0.87	0.13	0.35	0.25	0.26
Ferry Morse	24.32	17.43	13.38	9.50	5.81
GSN	2.39	1.46	0.06	0.05	0.03
Harris Moran	5.74	5.91	4.38	1.34	0.36
Heinz	8.16	11.51	13.95	20.42	32.33
Hunts	0.97	1.50	1.80	1.42	1.21
Ochoa	-----	-----	-----	0.00	0.01
Ohio State	0.02	0.03	0.04	0.00	0.00
Orsetti	3.57	10.38	19.20	25.14	25.71
Peto	22.43	19.43	17.14	12.92	8.63
Rogers NK	4.90	6.90	5.67	4.94	4.29
Sunrise	0.01	0.00	-----	0.00	-----
Sunseeds	7.83	5.70	5.93	3.88	3.43
United Genetics	-----	-----	0.01	-----	-----
Van den Bergh	-----	-----	-----	1.57	3.13
Unknown	0.27	0.23	0.02	0.03	0.03

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1991-1995.

Table 2.14. Average Levels of Selected Quality Parameters for Loads Inspected During 1995, by Seed Company

Seed Companies	Average Quality Rankings For 1995			
	Mold	Limited Use	Soluble Solids	Color Reading
	----------Percent----------			
Asgrow	1.27	2.58	5.14	24.59
Campbell	1.11	3.23	5.41	24.80
Delmonte	0.50	3.50	6.00	22.00
Derutter	0.80	4.10	4.96	23.40
Eclipse	1.11	2.53	5.33	24.76
Ferry Morse	1.08	2.18	5.18	25.12
GSN	1.10	4.60	5.16	24.93
Harris Moran	1.15	1.99	5.24	25.34
Heinz	1.25	1.74	5.06	23.82
Hunts	1.50	2.48	5.07	23.68
Ochoa	0.40	5.20	5.20	28.10
Ohio State	2.00	3.00	4.60	22.00
Orsetti	0.86	2.08	5.19	23.41
Peto	1.23	2.45	5.33	24.46
Rogers NK	0.94	2.88	5.39	24.55
Sunrise	-----	-----	-----	-----
Sunseeds	1.66	2.26	5.13	23.85
United Genetics	-----	-----	-----	-----
Van den Bergh	1.00	3.49	5.21	24.38
Unknown	1.00	5.10	5.21	22.50
State Average	1.30	2.10	5.21	23.90

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1991-1995.

realized that its varieties were no longer competitive [Angell--personal communication]. Harris Moran, which currently controls less than 1 percent of the market, may be unable to remain in the processing tomato seed business unless it can increase its market share.

The market share of seed companies usually hinges on the popularity of one or two varieties. Since varieties tend to remain popular for only a few years, seed companies must constantly develop replacement varieties to help them maintain their market position. For six years a Ferry Morse variety called Hybrid 785 was the number one variety. It controlled 10 percent of the market and generated annual revenues close to $5 million. Today, the same variety is close to number twenty on the seed sales list and controls only 1 percent of the market [Jacobs, Nichols--personal communication]. On the other hand, eight years ago Asgrow Seed company had almost no market share while today it controls approximately 9 percent of the market [Angell--personal communication]. Orsetti's market share increase was due almost entirely to the increased popularity of the current number one variety--BOS 3155. As a result, Orsetti Seed Company went from grossing less than $1 million from the sale of processing tomato seed during the early 1990s, to grossing over $7 million during 1995 [Stevens--personal communication].[24]

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[24] The gross revenues estimate is based on a price of $215 per 100 thousand seeds. However, since Orsetti Seed Company discounts the seed price to seed dealers by an average of 31 percent, Orsetti Seed Company grosses approximately $148 per 100 thousand seed unit. Assuming that there are 317,000 acres of processing tomatoes, and assuming that BOS 3155 controls approximately 26 percent of the seed market (PTAB data), 81,500 acres are planted with BOS 3155. It was further assumed that growers use an average of 60,000 seeds per acre.

Several of the larger processors also are involved in breeding processing tomato seed including: Van den Bergh Foods, Heinz and Campbell. The companies entered the seed breeding business to earn money via seed sales to contracted and non-contracted growers, and to gain greater control over the characteristics of the varieties they process. For example, Heinz is interested in varieties with high viscosity which is needed to produce high quality catsup [Angell--personal communication].[25] Another example is Campbell. Twelve years ago Campbell grew none of its own varieties, while today 50 percent to 55 percent of its contracted tons are produced using in-house varieties [Kuehn--personal communication]. Van den Bergh Foods, which several years ago sold none of its own varieties, plans to increase the use of its own seeds from 7 thousand to 20 thousand loads [Hirahara--personal communication].

II.3.2. Who Seed Companies Develop Varieties For:

Seed companies strive to develop varieties that satisfy the needs of both growers and processors. However, since processors play a dominant role in the selection of varieties, it has been argued that seed companies are more concerned about satisfying processor rather than grower objectives [Mullen--personal communication]. This argument has some merit since seed companies refrain from

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[25] However, the soluble solids (sugar) of Heinz varieties are somewhat lower (averaging between 4.8 percent and 4.9 percent) than many other varieties on the market [Angell--personal communication]. Despite this, many of the Heinz varieties are at the top of the variety use list [Mullen--personal communication]. This has partly occurred since Heinz is one of the largest processors, and over 80 percent of its contracted acreage is planted with Heinz varieties [Miyao--personal communication].

spending large sums of money to develop varieties that will only capture 2 percent of the market. Especially if processors are unlikely to include them on their approved variety lists [Rivara--personal communication].[26] To prevent this from occurring, seed companies work closely with processors and dealers on a year round basis to make certain their research and development activities correspond to the processors' needs [Angell--personal communication]. However, when seed companies identify a characteristic that works extremely well for growers, like field holding or increased yield potential, they attempt to incorporate the characteristic into new varieties. Seed companies realize that growers have developed their own strategies to avoid purchasing unprofitable varieties [Herringer--personal communication].

To minimize risk and uncertainty, seed companies ask processors which varieties and variety characteristics they prefer as early as eighteen months before the actual purchase date. There are several reasons why seed companies require so much lead time. First, a significant amount of time is required to plan the production of each variety since a number of steps are involved in the production process. After seed companies determine which varieties they are going to produce, they spend a number of months gathering the seed stock, especially for new varieties, to make certain they have enough seed on hand to produce the quantity they expect to sell.[27] It also takes time to prepare the inbred lines needed to produce hybrid seed. For

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[26] Seed companies spend an enormous amount of time and money breeding new and improved processing tomato varieties. A typical seed company spends $750 thousand dollars annually on its breeding program which includes the salaries of the breeders, quality labs, and field trials [Stevens--personal communication].

[27] One of the reasons BOS 3155 has been in short supply is because the seed company did not have sufficient time to produce the amount of seed demanded. At one time, Orsetti Seed Company was only able to satisfy 60 percent of demand [Stewart and Storz--personal communication].

example, to ensure the availability of hybrid seed for 1996, the inbred lines were identified and propagated no later than January, 1994. Second, the seed stock is then shipped to contractors who need time to distribute the seed to each seed grower. Third, a number of months are required to grow the plants and harvest the seed. Tomatoes are harvested for as long as three months to extract as much seed as possible from each plant [Stewart and Storz--personal communication]. Fourth, some seed companies such as Asgrow Seed Company, perform a number of quality checks on the seed before it is sold which adds more time to the planning horizon. For example, Asgrow Seed Company seed sold during the 1995 season, was produced during the Fall of 1993 [Angell--personal communication].

II.3.3. Production of Hybrid Seed:

Since the inbred lines used to produce hybrid seed must be hand pollinated, an enormous amount of labor is required to produce enough seed to meet the demand of California's processing tomato growers. If the seed companies relied on domestic labor, the cost of hybrid seed would be prohibitive. As a result, seed companies produce their seed in developing countries such as China, Thailand, and India where labor is much less expensive. The location chosen depends on the availability of foreign managers, and the amount of control the seed company is able to exert over the production operation [Mullen--personal communication].

Seed companies produce their seed in several different locations to reduce the risk of losing the crop due to a natural calamity or political upheaval [Angell--personal communication]. For example, some companies have had a particularly

difficult time coordinating the delivery of seed produced in India [Nichols--personal communication]. In addition, there tends to be tremendous variation in the quality of seed produced overseas, and sometimes the seed gets delayed in transit [Yerxa--personal communication]. Thus, Campbell divides the production of its seed between China and India [Kuehn--personal communication], while Orsetti Seed company produces its seed in Thailand, India and China [Orsetti--personal communication].

During the early years of overseas production, seed companies gave their foreign subsidiaries one year advance notice to produce a particular variety that was needed for the up-coming crop season. Petoseed Company, among others, has now shortened the production turn-around time to only five months. Thus, if Petoseed requests seed in August, it is able to obtain the seed before planting begins in January. In contrast, Harris Moran entered the hybrid seed market somewhat later and has not yet been able to consistently produce its seed in less than one year. This gives Petoseed a decisive marketing advantage since it is able to introduce new varieties somewhat earlier which permits them to capture a large share of the potential market [Jacobs--personal communication].

II.3.4. Setting Seed Prices:

Although the seed companys' suggested retail prices for varieties are usually very similar, the prices growers pay for seed are frequently lower, and on rare occasions higher, than the suggested prices. However, the discounts given across varieties are more or less uniform and seldom exceed 10 percent [Stewart and Storz--personal communication]. Thus, in most cases, there is not much variability within

either hybrid or OP seed prices, although hybrid seed sells for eight to ten times more than OP varieties. Most hybrid seed prices are within 5 to 10 percent of each other regardless of the type of processed products they are used for. Although growers indicated that hybrid seed purchased for the 1995 season ranged in price from $85 to $315 per one-hundred thousand seed unit, most hybrid varieties were sold for prices that ranged between $180 and $230 per one-hundred thousand seed unit (Table 2.15). In contrast, OP varieties sold for between $10 and $45 per pound.[28]

Variety price differences are strongly influenced by processors since they have a decisive impact on which varieties are purchased [Stevens--personal communication]. Seed price differences are strongly influenced also by differences in the package of characteristics contained within each variety [Stewart and Storz--personal communication]. Newer varieties tend to have the highest prices since they have superior characteristics and cost more to develop and produce. Variety shortages also tend to push the price upward [Brown--personal communication]. For example, due to the popularity of BOS 3155, shortages have developed on several occasions which enabled dealers to sell the variety at full list price. If growers did not have other variety options, the suggested retail price of BOS 3155 might be much higher [Stewart and Storz--personal communication].

Campbell is the only seed producer that sells its seed to growers at a discount since it makes most of its profits from end products such as soup.[29] Campbell is

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[28] On average, there are approximately 160,000 seeds per pound.

[29] Campbell sells its seed for an average of $70 less than the average market price. However, there are other varieties that sell for only $20 more than Campbell's varieties [Kuehn--personal communication].

Table 2.15. Grower Estimates of the Prices of Hybrid Tomato Seed (per 100,000 seed unit) Purchased for the 1995 Growing Season, by Region

Growing Region	Variety Prices			
	Average	Lowest Price	Highest Price	Standard Deviation
	----------Dollars----------			
Region I	211.60	85.00	300.00	32.55
Region II	192.10	154.00	315.00	45.68
Region III	200.00	N/A	N/A	N/A
State	202.50	85.00	315.00	38.47

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

currently debating the wisdom of giving seed discounts since it receives no direct benefit in the form of lower raw product prices. However, Campbell charges a premium price for its end products since it believes that its products contain superior characteristics [Kuehn--personal communication]. Some of the other processors also previously subsidized the price of their seed, but for the most part have stopped. Tri-Valley still occasionally subsidizes the price growers pay for seed for varieties it intends to use in its processing plants [Tarry--personal communication]. In addition, when The Morning Star Packing Company chooses varieties, it factors in the seed price as part of its incentives and deductions program [Rufer--personal communication].

If seed companies believe they have a variety that will capture a large share of the market, they set the suggested retail price somewhat higher than some competing varieties. On the other hand, if they have a variety that is projected to capture only 2 percent to 3 percent of the market, they set the price of the variety somewhat lower.[30] For example, due to the reduced demand for Brigade, the suggested retail price quickly fell from $215 to $185 per one-hundred thousand seed unit [Hirahara--personal communication].

The suggested retail price also may be affected by the size of the seed. If the seeds are very large there may only be 115 thousand seeds per pound. If the seeds are small, there may be as many as 240 thousand seeds per pound. In Taiwan and China the seed is sold by the kilo to seed companies. Brigade is a small seed and has

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[30] Most varieties only capture 2 to 3 percent of the market since they have some shortcoming such as poor adaptability or inconsistency [Rivara--personal communication].

as many as 230 thousand seeds per pound. Most of the other hybrid varieties contain an average of 160 thousand seeds per pound. Thus, Brigade has a significant price advantage over many of its larger seed competitors [Hirahara--personal communication]. If dealers sold the seed by the pound, growers would tend to buy the smaller seed since it is cheaper.[31] To prevent this from occurring, dealers sell hybrid seed in 100 thousand seed units [Brown--personal communication].[32] However, since OP seed is much less expensive, dealers continue to sell it by the pound [Timothy--personal communication].[33]

In some cases, large growers may pay lower prices since they buy more seed than small growers [Storz--personal communication]. A one-hundred acre producer may pay much closer to retail than a four thousand acre producer [Rufer--personal communication]. Some growers believe they are able to negotiate lower seed prices if they consistently conduct business with one dealer [Mast--personal communication].

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[31] Some growers purchased air precision planters because it allows them to use a much lower seeding rate and smaller seeds. In contrast, mechanical precision planters clumps the seed which requires a higher seeding rate per acre than when precision planters are used. Many growers did not want to buy the smaller seed because they lacked the proper equipment to plant it and because it was difficult to handle. In addition, air planters are reportedly not as durable as mechanical planters and they do not always work with the desired degree of accuracy [Stewart and Storz, Robertson--personal communication].

[32] Most of the seed industry packages their seed in 100 thousand seed units and charge by the 1000 seed. For example, the suggested retail price of BOS 3155 is $2.25 per 1000 seed. The only companies that do not sell their seed in 100 thousand seed units are Heinz and Campbell, which sell seed by the pound, and Asgrow which sells its seed in 150 thousand seed units. Both Heinz and Asgrow charge by the 1000 seed unit, but the overall charge is based on the number of seeds in the package. Campbell, which until 1995 sold its seed by the pound, in future years will charge by the 1000 seed unit while still using pound packages [Stewart and Storz--personal communication].

[33] Seed companies set the price of their varieties based on the average size of all of their seed. For example, 50 percent of the varieties may be large, 25 percent medium and 25 percent small. To avoid confusion, the seed companies set the price based on the cost of producing average sized seed. Thus, the seed price is based more on what the market can bear than on production costs [Stewart and Storz--personal communication].

However, the seed price for some varieties, such as those sold by Heinz and Asgrow, are the same regardless of the number of acres grown, while other seed companies require dealers to keep their seed prices within a narrow range [Robertson--personal communication]. In addition, since the industry has fewer growers than in the past, the growers spend more time with each other comparing prices which has eliminated many of the price differences within and between growing regions [Stewart and Storz--personal communication].

Seed companies also sometimes cut the price, extend terms or offer some other kind of incentive to convince dealers to carry unpopular varieties. For example, Harris Moran offered dealers a 50 percent discount if they agreed to purchase an unpopular variety called Vega [Jacobs--personal communication]. However, this strategy seldom works. Although one seed company reduced the price of an old variety by 20 percent, it was unable to sell it since it was not included on any of the processors' approved variety lists. Growers were unwilling to buy the variety, even if the seed company reduced the price by 50 percent, because they were concerned that processors would be unwilling to take their harvests [Brown--personal communication]. However, seed companies and dealers are usually able to sell some of the older seed since some growers believe that older seed stocks are stronger and outperform new seed [Timothy--personal communication].

II.3.5. Role of Seed Dealers:

Ten seed dealers sell processing tomato seed directly to growers in California. TS&L Seed Company controls approximately 40 percent of the market followed by

Ag-Seeds Unlimited (25-30 percent) and Lockhart Seeds (10 percent). The remaining companies control 20 to 25 percent of the market [Storz--personal communication]. Dealers attempt to select varieties for each grower that are compatible with the needs of the processors they sell to, contain the best mix of grower characteristics such as yield, disease and nematode resistance and are compatible with the growers' cultural practices [Hirahara--personal communication]. They also take into consideration the harvest schedule and whether the harvest will be completed in early summer or late fall since regional climatic conditions can affect the yield and quality of certain varieties [Brown--personal communication].

Since there are usually several dozen or more new varieties that enter the market each year, it is difficult for dealers to gauge which of the new varieties will be the most successful [Timothy--personal communication].[34] As a result, seed dealers tend to be conservative in their booking since they want to avoid holding costly inventory. The quality of the seed also can decline during storage and the following year it may not be as popular. If dealers have as part of their inventory, old varieties that are not selling well, they may sell them for as little as one-third of the original price [May--personal communication].[35] Thus, seed dealers generally attempt to book 80 percent of their projected sales and purchase the rest on the spot market. Seed dealers also have expanded the size of their market since there are economies of

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[34] Only five to ten of the new varieties sold each year have commercial potential [Stewart and Storz--personal communication].

[35] When seed companies sell seed to a dealer, they transfer ownership to the dealer who is then free to deviate from the suggested retail price as much as desired [Stewart and Storz--personal communication].

scale in purchasing larger volumes of seed. In addition, if a variety is no longer popular in one part of the state, they may be able to sell the remaining inventory in a different region [Stewart and Storz--personal communication].

To reduce some of the uncertainty involved with selecting varieties, some seed dealers perform their own variety evaluations because they have found that the data obtained from seed companies, inspection stations and state run field trials are not always in agreement [Brown--personal communication]. In the past, TS&L Seed Company tested 175 varieties (1600 samples) in its own laboratory to measure consistency, stability and other traits. The information helped the company select the best new varieties while allowing it to focus its sales effort on a limited and manageable product line. TS&L Seed Company was then in a better position to learn the strengths and weaknesses of each variety while improving its inventory forecasts [Storz--personal communication]. This is very important since if seed companies are unable to sell their inventory during the current crop year, it may have to be sold in future years at a large discount to compete with new and improved varieties. As a result, growers lose some of their freedom of choice since dealers encourage them to purchase the varieties included as part of their inventories.

II.3.6. Dealer Strategies to Attract Grower Business:

Dealers have developed a number of strategies to attract grower business. First, they must make certain they have access to the leading varieties such as BOS 3155 and Brigade. This attracts growers who also are likely to purchase other varieties [Hirahara--personal communication]. Second, dealers must have adequate

stocks of minor and niche varieties since growers usually only plant a portion of their acreage to the leading varieties. Third, to ensure adequate supplies, dealers sell a large number of varieties produced by the majority of seed companies [Miyao--personal communication]. Fourth, they offer inducements, such as a six month grace period, before growers have to pay for their seed [Woolf--personal communication]. In addition, many dealers offer to calibrate growers' planters, and they provide technical assistance when requested [Kennedy--personal communication].

Dealers complain that the market is dominated by a few popular varieties which are not always available. This occurs either because there are limited supplies, which has been a problem for BOS 3155, or because they are proprietary varieties (approximately 41 percent of the inspected loads) bred by large processors that are either sold directly to growers or through one selected dealer. For example, TS&L is the exclusive dealer for Asgrow Seed Company, while Ag-Seeds Unlimited is the exclusive dealer for Heinz [Kennedy--personal communication]--although growers also are able to purchase seed directly from Asgrow and Heinz. Asgrow opted to contract with one dealer for several reasons. First, when seed is sold through more than one dealer, the dealers tend to reduce the price to a bare minimum. Second, Asgrow works closely with TS&L on the field trials and evaluations so that both parties understand the strengths and weaknesses of each variety. Third, unlike some dealers, TS&L has experienced personnel who provide quality service to its customers [Angell--personal communication].

The seed market is further tightened since the three leading non-proprietary varieties control another 30 percent of the market. If a dealer is unable to obtain the

leading and proprietary varieties, its effective market is reduced to only one-third of the total acreage. In addition, since growers frequently purchase their seed from one source, a dealer without access to these varieties is unlikely to obtain business for the remaining varieties [Hirahara--personal communication].[36] For example, Orsetti Seed Company requires dealers to finance the production of BOS 3155 seed in China if they want to obtain seed.[37] This limits the amount of BOS 3155 small dealers are able to purchase unless they are able to convince their growers to pay for seed deliveries far in advance [Hirahara--personal communication].

Small dealers also are at a competitive disadvantage since large seed companies sometimes prefer to work exclusively with only one or two large dealers to maximize market promotion and to avoid price cutting competition [Orsetti--personal communication]. For example, although BOS 3155 has a suggested retail price of $215 per hundred-thousand seed unit, it is sold to dealers at a discount ranging between 28 and 34 percent, and sometimes higher. The dealer can either retain the discount or use it as leverage to attract business. Dealers sometimes sell seed at only 3 percent above cost to make a sale and to fend off other dealers [Angell--personal communication].

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[36] Several years ago, growers usually purchased all of their seed from one dealer. Today, less than 20 percent of the growers purchase seed from one dealer. This change has occurred for several reasons. First, some varieties, such as those produced by Asgrow and Heinz, are only sold through one dealer. Second, growers want to capitalize on the competitive nature of the market to bargain for the best price since hybrids cost considerably more than OPs. Third, there is usually a shortage of some of the popular varieties such as BOS 3155. This forces growers to scour the marketplace for the seed they need [Stewart and Storz--personal communication].

[37] Dealers who want to sell BOS 3155, must make a deposit of three-quarters of the total sale price by September 27th to pay for seed production in China [Hirahara--personal communication].

II.3.7. Impact of Hybrids on Dealer Risk and Uncertainty:

There are several reasons why the introduction of hybrid varieties increased the risk and uncertainty confronting seed dealers. First, it costs far more to produce a pound of hybrid seed than it costs to produce a pound of open pollinated seed. Production costs increased from approximately $6 per pound of OP seed to approximately $150 per pound of hybrid seed. Due to the much larger financial outlay, seed companies now require seed dealers to pay for their seed up-front. At one time, seed dealers were not required to pay for the seed they purchased until after it was sold at the conclusion of the seed selling season in June. They also were not obligated to book their varieties very accurately and they were not committed to the booking they had agreed to. In addition, they could return anywhere from 25 to 100 percent of the seed they were unable to sell. Today, dealers must accurately forecast their inventory since they have to pay for the seed within thirty days, and they are unable to return any of the unsold seed. In addition, dealers cannot afford to hold large inventories since new and improved hybrids are constantly being marketed. This makes it difficult to sell hybrid seed stocks that remain from previous seasons [Stewart and Storz--personal communication].[38]

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[38] During the 1997 season, seed dealers reduced the price of their hybrid seed by an average of $40 per 100,000 seed unit. This occurred since there was a tremendous over-supply of tomato paste which significantly reduced the paste price. Processors responded by requiring growers to plant varieties with higher soluble solids. Higher soluble solids reduces the cost of producing tomato paste since less energy is expended to boil off excess water. Since seed dealers had many varieties with unacceptably low soluble solids potential, they were forced to drastically reduce seed prices to attract business [Storz--personal communication].

CHAPTER III

TOMATO GENETICS, BREEDING AND TRAIT SELECTION

The purpose of Chapter III is to provide a description of tomato genetics and the role genetics plays in the breeding of improved processing tomato varieties. The first part of the chapter provides a background of tomato genetics. The next few sections describe breeding methods, the role of germplasm and breeding objectives. This is followed by a discussion of the types of characteristics desired by growers and processors. The last part of the chapter describes the approaches taken to breed certain characteristics such as soluble solids, yield potential, color, viscosity and a number of other traits.

III.1. Background of Tomato Genetics:

Processing tomatoes belong to the nightshade or Solanaceae family and the genus Lycopersicon which originated in a narrow elongated strip extending from northern Chile to Ecuador [Gould, 1992]. All members of the genus are annual or short-lived perennial herbaceous diploids with a somatic chromosome number of twenty-four [Tigchelaar, 1986]. They are all self-compatible and exclusively inbreeding [Taylor, 1986]. Cultivated and wild relatives of commercially grown tomatoes are still found in a narrow region of the Andes mountains in Peru, Ecuador, Bolivia and in the Galapagos Islands [Tigchelaar, 1986].

Although wild tomatoes originated in South America, the ancestor of modern day commercially grown processing tomatoes was more than likely the cherry tomato

(Lycopersicon esculentum var. cerasiforme) which was first domesticated in Mexico hundreds of years ago by the indigenous people [Kalloo et al, 1991].[1] Circumstantial evidence supports the contention that Mexico was the probable region of domestication. The hereditary enzyme variants found in old European cultivars are much more similar to the primitive cultivars and cherry tomatoes found in Mexico than they are to the wild species found in the Andean region. It is also evident that tomatoes had already reached an advanced state of domestication in Mexico and Latin America before they were introduced to Europe during the sixteenth century. Unlike wild varieties, the first varieties cultivated in Europe bore large fruit. In addition, according to written descriptions from that period, a good many sizes, shapes, and colors were known [Rick, 1978].

III.1.1. Description of the Lycopersicon Species:

The genus Lycopersicon consists of nine species which have been divided into two subgenera: Eulycoperscion, which includes all of the cultivated species, and Eriopersicon. The species were divided into two subgenera partly on the basis of their ability to interbreed. Although in nature intraspecific crosses succeed readily among members of the Eulycoperscion subgenera, the member species of the Erioperscion subgenera are incapable in nature of interbreeding with member species of the Eulycoperscion subgenera. However, despite the great difficulty, breeders are sometimes able to achieve crosses between the Eulycoperscion and Eriopersicon

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[1] Fruits of the wild species L. cerasiform and L. pimpellifolium are also consumed. The other species are useful for their quality attributes which are backcrossed into the cultivated varieties [Gould, 1992].

species [Gould, 1992]. The first of the seven Eulycoperscion species, Lycopersicon esculentum, is represented in nature by its variant cerasiform, which has served as the primary species used to breed commercially grown tomatoes. The other six, L. pimpinellifolium (currant tomato), L. cheesmanii, L. hirsutum, L. pennellii, L. chmielewskii, and L. paraviflorum, are wild species. The two members of the Eriopersicon subgenera, L. chilense and L. peruvianum, also are both wild species [Kalloo et al., 1991].

L. pimpinellifolium is typically encountered at relatively low altitudes in Peru. It is the only wild species which has natural introgression with L. esculentum. This either indicates that it is the direct ancestor of L. esculentum, or that it evolved in parallel from a green fruited ancestor [Taylor, 1986]. Since L. pimpinellifolium contains many commercially useful genes, it has played an important role in the evolution of the cultivated tomato [Tigchelaar, 1986]. For example, genes from L. pimpinellifolium have frequently been backcrossed into L. esculentum to provide traits such as resistance to the Fusarium wilt diseases, and more recently to Bacterial speck [Taylor, 1986].

L. cheesmanii is only found on the Galapagos Islands and has evolved separately from the other species due to its extreme geographic isolation. Although L. cheesmanii is also closely related to L. esculentum, and can be easily hybridized with cultivated tomatoes, it has had less commercial value since it lacks useful disease resistance. However, a jointless pedicel trait has been transferred from L. cheesmanii

into commercial cultivars, and a salt tolerant trait contained within the species may someday be needed for crops in heavily irrigated areas [Taylor, 1986].[2]

L. hirsutum is characteristically found at high elevations in moist river valleys from 500 to 3000 meters above sea level. This is the highest elevation above sea level where lycopersicon species are found. It contains a number of potentially useful genes including resistance to Bacterial speck, fungal diseases, and root knot nematodes. Each of these traits is gradually being backcrossed into cultivated tomato varieties. It also contains resistance to several other fungal diseases and viruses, and it has natural resistance to insect pests such as spider mites and aphids. In addition, the species is being investigated for genetic tolerance to cold environments since it grows at a high elevation [Taylor, 1986].

L. parviflorium and L. chmielewskii are two closely related species which are found in the relatively isolated inter-Andean region of Peru. Both species grow in relatively moist habitats along the rocky banks of small streams. Plant breeders have expressed interest in the high soluble solids (sugar content) of both L. parviflorium and L. chmielewskii. When L. chmielewskii was backcrossed into the commercial cultivar VF-145, the soluble solids content increased from 5 percent to 7.5 percent, while adequate size and color were maintained.

L. pennellii occupies a fairly restricted distribution along the coast of Peru. Although it is sometimes found at low altitudes, it is typically encountered between 500 and 1500 meters above sea level and can survive in especially hot and dry areas.

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[2] When genes from a coastal population of L. cheesmanii were backcrossed into domesticated cultivars, the plants were able to survive and produce fruit when irrigated with up to 70 percent seawater [Taylor, 1986].

As a result, plant breeders have investigated the possibility of transferring drought resistant traits into cultivated varieties [Taylor, 1986].

Scientists also are working to overcome the genetic barriers which make it difficult to cross members of the Eriopersicon subgenus with the cultivated forms of L. esculentum by using techniques such as embryo culture. The removal of the barriers may lead to significant improvements in cultivated tomatoes since L. peruvianum contains many agronomically important characteristics that may one day be needed by the processing tomato industry [Kalloo, 1991, Taylor, 1986]. In particular, it is highly adaptable to environmental extremes. This includes an ability to tolerate very cold temperatures, and it has remarkable variability, especially in terms of disease resistance. For example, accessions of L. peruvianum are available which carry resistance to Early blight, Leaf mold, Fusarium wilt, Septoria leaf spot, Bacterial wilt and several viruses [Taylor, 1986].

III.2. History of Tomato Breeding:

During the latter part of the seventeenth century, before institutions were officially designated to breed tomatoes, only 4 types of tomato varieties were known: yellow, golden, red and white. By 1700, seven types were known including one that was large, red, and smooth. Differences in breeding objectives among the countries that bred tomatoes emerged early. For example, the Italians selected varieties with a wide range of characteristics, while the varieties developed by northern Europeans differed primarily in color. In 1837, Thomas Bridgeman noted that large squash and

cherry shaped tomatoes were being grown in the U.S., and in 1847 he added large yellow and pear shapes.

By 1863, the number of tomato varieties listed in American seed catalogs had grown to twenty-three. By the turn of the century, the number of varieties available to growers had increased to several hundred.[3] However, no new varieties were developed in the U.S. prior to 1860, and serious breeding efforts have only been undertaken in this country since the 1890s. The initial U.S. breeding efforts were undertaken by scientists at public institutions who wanted to create varieties with improved disease resistance. One of their first successful releases occurred in 1912 when they released a Fusarium wilt-resistant variety called Louisiana Wilt Resistant [Stevens and Rick, 1986]. Although new varieties were starting to be developed in America, and many European varieties had been introduced, seedsmen frequently listed identical or nearly identical varieties as separate and unique. As a result, there was considerable confusion regarding the exact number of true varieties. In 1886, Bailey, of the Agricultural College in Michigan, found that only sixty-one of 170 samples tested represented true varieties, many of which were very similar [Gould, 1992].

Table 3.1 lists many of the varieties included in American seed catalogs between 1868 and 1937. Some of the varieties remained popular for many years, while other varieties were only included in the catalogs for one year. For example, although Trophy and Cedar Hill were both introduced at the same time, the former

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[3] Between 1870 and 1893 a gardener named Livingston, who is considered to be the first American tomato breeder, introduced thirteen new varieties which he developed using a single plant selection breeding system.

Table 3.1. Popular Tomato Varieties Listed in Seed Catalogues Between 1868-1936

Variety	Period Listed	No. Years	Variety	Period Listed	No. Years
Cherry Red	1868-1936	69	Red Apple	1889-1889	1
Red Pear Shaped	1872-1936	65	Atlantic Prize	1891-1907	17
Cedar Hill	1872-1873	2	Ignotum	1891-1898	8
Trophy	1872-1926	55	Peach	1891-1930	40
Charter Oak	1872-1874	3	Dwarf Champion	1892-1936	45
Canada Victor	1874-1892	19	Royal Red	1893-1907	15
Arlington	1874-1878	5	Stone	1893-1936	44
Hathaway's Excelsior	1876-1886	11	Buckeye State	1895-1915	21
Early Conqueror	1876-1893	18	Dwarf Aristocrat	1893-1903	8
Little Gem	1879-1883	5	Imperial	1896-1898	3
Green Gage	1879-1883	5	Honor Bright	1898-1909	12
Triumph	1879-1880	2	Magnus	1901-1914	14
Acme	1879-1930	52	Matchless	1901-1922	22
Paragon	1880-1892	13	Nolte's Earliest	1902-1907	6
Essex Early Hybrid	1881-1912	32	Yellow Pear Shaped	1902-1936	35
Golden Trophy	1879-1882	4	Earliana	1904-1936	33
Turk's Turban	1880-1882	3	Chalk's Early Jewel	1905-1936	32
Early Trophy	1881-1881	1	Quarter Century	1905-1908	4
Hundred Day	1881-1890	10	Dwarf Stone	1905-1936	32
Perfection	1882-1922	41	Purple Dwarf	1905-1908	4
Alpha	1882-1883	2	Globe	1906-1936	31
Favorite	1883-1907	25	Ponderosa	1906-1936	31
Queen	1883-1890	8	June Pink	1907-1936	30
Optimus	1885-1911	27	Early Detroit	1909-1936	28
Golden Queen	1886-1936	51	Coreless	1911-1921	11
Beauty	1887-1929	43	Bonny Best	1916-1936	21
Cincinnati Purple	1887-1896	10	Avon Early	1921-1936	16
Cardinal	1887-1888	2	Gulf State Market	1921-1936	16
Yellow Plum	1887-1936	50	Greater Baltimore	1925-1936	12
White Apple	1887-1930	44	Cooper's Special	1926-1936	11
Yellow Cherry	1887-1930	44	Marglobe	1927-1936	10
Early Michigan	1889-1930	42	Morse's Special 498	1931-1936	6
Mikado	1889-1902	14	Break O'Day	1932-1936	5

Source: Wilbur A. Gould, Tomato Production Processing & Technology, Third Edition, Baltimore: CTI Publications, Inc., 1992, p 7.

remained popular for fifty-five years, while the latter remained popular for only two years [Gould, 1992]. However, even the most popular older varieties were gradually replaced by new varieties that either had improved growing characteristics, and/or possessed characteristics that reflected changes in consumers tastes and preferences. The most popular varieties were Red Cherry, Red Pear Shaped and Trophy [Tigchelaar, 1986]. Trophy, which was introduced in 1872, was the first of the large, fairly early, smooth, apple-shaped varieties.

III.2.1. Impact of the Tomato Harvester on Variety Development:

During the 1950s, plant breeders successfully developed varieties that could be machine harvested. The purpose of the harvester was to increase the harvesting efficiency of California's growers, while reducing their labor costs and dependence on an uncertain labor market. Members of the processing tomato industry recognized that in order to successfully use harvesters, processing tomatoes required greater firmness to protect them from machine damage, a compact vine and a very short fruit setting period so that most of the fruit would ripen at the same time. Unfortunately, the varieties with these characteristics also were susceptible to Verticillium wilt and Fusarium wilt. Although varieties were available with resistance to the two diseases, they had large indeterminate vines and bore large soft fruit.[4] Eventually, all of the

[4] Machine harvested varieties contain the *sp* (self-pruning) gene which results in a determinate (compact) vine and more concentrated flowering which are essential traits for machine harvesting [Tigchelaar, 1986]. Although other genes that control dwarf (*d*) and brachytic habit of growth are available, they result in poor yield and quality. This includes small fruit, soft fruit, low solids and poor color [Berry and Uddin, 1991].

desired traits were backcrossed into an OP variety (VF 145), which dominated the California processing tomato industry during the 1960s [Stevens and Rick, 1986].

III.2.2. Hybrid Seed Development:

Until the late 1970s, all of the commercial processing tomato varieties used worldwide were inbred lines.[5] Although hybrids can be created by crossing either two heterozygous or homozygous parents, conventional hybrid seed products (seed planted by a farmer) result from the controlled crossing of inbred lines. The best hybrids are identified through field evaluations and are then commercialized. Hybrids are generally superior to inbreds due to heterosis (hybrid vigor), which manifests itself most strongly in the F_1 generation and then decreases progressively in the following generations.[6]

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[5] The processing tomato industry refers to inbred lines as open pollinated varieties (OPs). However, there are significant differences between inbred lines and OPs. The parent of an OP is the cultivar itself. OPs are generally highly heterozygous and are similar to randomly mating populations. In contrast, an inbred is generally genetically homogeneous, homozygous and phenotypically uniform. Inbred lines are created by continually self-pollinating each generation until homozygosity is achieved. Homogeneous indicates that the plants are identical. Homozygous means that an individual has identical alleles (sequence of DNA along a particular chromosome) at a locus (the position on a chromosome occupied by a particular gene or one of its alleles) [Ward--personal communication].

[6] Mid-parent heterosis occurs when the performance of an F_1 hybrid, created by crossing two parents, exceeds the mean of the two parents. High-parent heterosis occurs when the performance of an F_1 hybrid created by crossing two parents, exceeds the performance of the best parent. There are several theories which attempt to explain why heterosis produces superior offspring. The first, called "overdominant gene action", postulates that if the phenotype of Aa>AA or=aa (the heterozygote exceeds both homozygote phenotypes), the gene action is overdominance. The second, called the "repulsion phase link of genes exhibiting dominance", postulates that if Aa=AA>aa and Bb=BB>bb, and the dominant phenotype in both cases contributes to increased yield; the performance of the F_1 of the cross AAbbxaaBB will exceed the performance of the parents since it will be heterozygous at both loci (AaBb) [Ward--personal communication].

Hybrid seed production was partly motivated by the desire of the processing tomato industry to produce superior varieties.[7] Hybrids tend to have greater yield potential than OPs (an average of 5 to 10 tons more per acre), higher soluble solids, improved color and viscosity and other desirable processing traits. Hybrid seed production also was motivated by seed companies that wanted to prevent competitors from producing and selling identical varieties. There was little incentive for seed companies to create new OP varieties since competitors could easily reproduce the same variety. They could then freely sell it on the open market while spending little time and money of their own to develop new varieties. Although in theory the Plant Variety Protection Act (PVPA) granted seed companies proprietary rights to their varieties, competitors were able to legally sell a slightly modified version of the variety with nearly identical yield and quality attributes.[8] Seed companies are able to prevent this from occurring by keeping secret the identity of the inbred lines used to create their hybrids. As a result, seed companies achieve de facto proprietary protection.[9]

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[7] Members of the processing tomato industry also indicated that superior varieties can be produced more quickly by developing hybrids rather than new OPs. However, this is not necessarily true. Before new hybrids are created, new inbred lines must first be developed. Breeders do not rely on the inbreds that are sitting on the shelf. Rather, they are constantly in the process of developing thousands of new inbreds [Ward--personal communication].

[8] The PVPA was created to protect seed companys' proprietary rights to their OP varieties. However, under the original wording of the PVPA, if a company found a small mutation in a legally protected OP, they could file it for protection under the PVPA as a new variety. Recently (1994), the PVPA was modified to state that new varieties derived from an older protected OP must exhibit distinct differences that are economically important [Stevens--personal communication].

[9] In the future, it may be possible to use genetic markers to identify the traits that were derived from an OP variety. Thus, seed companies will be able to collect a fee from any company that backcrosses one or more traits from their OPs into competing OPs [Remonda--personal communication].

III.2.3. Breeding and the Role of Germplasm:

There are numerous examples of single genes that have been used to improve tomato varieties. Table 3.2 lists some of the genes that have been used to improve tomato varieties. For example, at least eight different pathogens such as Fusarium wilt races I and II, Verticillium and Late blight are controlled with genes that have mostly been backcrossed from wild species into commercial varieties.[10] Other genes, such as the *u* gene, helped to improve uniform ripening, while the *sp* gene causes tomato plants to grow a compact vine [Rick, 1978]. Individual genes also have been used to provide resistance to nematodes, improve color and ripening and to create a jointless pedicel [Tigchelaar, 1986].

Despite the advances briefly summarized above, no commercial varieties have yet been developed that are able to tolerate excessive heat, excessive water, drought and/or salinity. Few varieties are resistant to insect pests and bacterial diseases or have complex resistance [Garanko, 1991]. In addition, sometimes genes that are desired to improve one facet of the tomato harm another aspect of the plant. For example, when tomato plants were bred to be mechanically harvested, several of the new vine characteristics, including determinate vines, resulted in lower soluble solids [George and Berry, 1992].

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[10] The backcross method of breeding is a popular way to transfer a single qualitative gene from one line to another line with otherwise superior attributes. Continued backcrosses are made to the desirable parent, and selection is practiced for the trait being transferred. In the end, the newly developed cultivar will be the same as the original parent except that it now includes the backcrossed trait(s) [Pierce, 1991, Berry and Uddin, 1991].

Table 3.2. Examples of Single Genes That Have Been Useful for Tomato Improvement

Gene Designation	Gene Symbol	Variety
Growth Habit		
Self-pruning	*sp*	Many
Brachytic	*br*	Redbush
Dwarf	*d*	Epoch, Tiny Tim
Potato leaf	*c*	Geneva 11
Jointless pedicel	*j-1*	Pen Red
	j-2	Many
Pest Resistance		
Leaf mold resistance	*Cf-1*	Sterling Castle
	Cf-2	Vetamold
	Cf-3	V_{121}
	Cf-4	Purdue 135
Fusarium immunity		
race 1	*I-1*	Pan American
race 2	*I-2*	Walter
Verticillium resistance	*Ve*	VR Moscow
Septoria resistance	*Se*	Targinnie Red
Late blight resistance	*Ph-1*	New Yorker
Alternaria resistance	*Ad*	Southland
Stemphylium resistance	*Sm*	Tecumseh, Chico III
Tobacco mosaic resistance	*Tm, Tm-2, Tm-2²*	
Curly top virus	?	C5, Columbia
Spotted wilt virus	Several genes, race specific	Pearl Harbor
		Rey de los Tempranos
Nematode resistance	*Mi*	Rossoll, VFN Bush
Fruit Characteristics		
Uniform ripening	*u*	Heinz 1350
High pigment	*hp*	Redbush
Green stripe	*gs*	Tigerella (novelty)
High beta	*B*	Caro-Rich
Old gold crimson	og^c	Vermillion
Low total carotene	*r*	Snowball
Tangerine	*t*	Sunray, Jubilee
Colorless peel	*y*	Traveller
Nonripening	nor^A	Long Keeper

Source: Edward C. Tigchelaar, Breeding Vegetable Crops, Avi Publishing Co., 1986, p. 145.

III.2.4. Breeding and the Role of Wild Germplasm:

Since the late 1930s, tomato breeders have become increasingly reliant on exotic sources of important genetic traits [Rick, 1986].[11] Disease resistance has been the most highly utilized trait found in wild germplasm. Starting with resistance to Fusarium wilt race I which was first reported in 1940, resistance to thirty serious diseases have been detected in wild germplasm, the majority of which have been bred into commercial varieties.[12] True breeding varieties with resistance to as many as six different diseases are commonplace, while as many as ten disease resistant traits have been combined in F_1 hybrid varieties. Without the use of these disease resistant traits, tomatoes could not be grown economically in many areas [Kalloo, 1991, Rick, 1986]. Table 3.3 lists disease resistance traits found in wild germplasm.

Although breeders have focused most of their efforts on transferring disease resistant traits from wild germplasm into cultivated varieties, there is an inexhaustible supply of unexplored diversity within the wild species [Tigchelaar, 1986]. For example, breeders have used wild germplasm to improve color, elevate soluble solids,

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[11] Twenty-eight tomato germplasm collections are scattered around the world and consist of 32,000 tomato samples. The Rick Center, at the University of California at Davis, has a unique collection comprising over 600 wild accessions [Garanko, 1991]. The two principal collections of tomato germplasm in the U.S. are those of the USDA/North Central Regional Plant Introduction Station at Ames, Iowa and the Tomato Genetics Stock Center (TGC) at the University of California at Davis [Rick, 1986].

[12] Some examples of disease resistant traits transferred from wild germplasm into commercial varieties are: resistance to Verticillium races I and II and resistance to root knot nematodes from L. peruvianum, and resistance to Fusarium wilt from L. pimpinellifolium [Kalloo, 1991].

Table 3.3. Disease Resistance Bred into Commercial Tomato Varieties from Wild Tomato Species

Disease	Inciting Organism	Source of Resistance
Bacteria		
Bacterial Canker	Corynebacterium michiganese	L. hirsutum, peruvianum, pimpinellifolium
Bacterial wilt	Pseudomonas solanacearum	L. pimpinellifolium
Bacterial speck	Pseudomonas tomato	L. pimpinellifolium
Fungi		
Leaf mold	Cladosporum fulvum	L. esculentum var. cerasiforme
Fruit Anthracnose	Colletotrichium coccodes	L. esculentum var. cerasiforme
Fusarium wilt	Fusarium oxysporum	L. pimpinellifolium
Late blight	Phytophthora infestans	L. pimpinellifolium
Corky root	Pyrenochaeta lycopersici	L. peruvianum
Leaf spot	Septoria lycopersici	L. esculentum var. cerasiforme, hirsutum, pimpinellifolium
Grey leaf spot	Stemphylium solani	L. pimpinellifolium
Verticillium wilt	Verticillium albo-atrum	L. esculentum var. cerasiforme
Nematodes		
Root knot nematode	Meloidogyne incognita	L. peruvianum
Viruses		
Curly top virus	CTV	L. peruvianum
Potato Y virus	PYV	L. esculentum var. cerasiforme
Spotted wilt virus	SWV	L. pimpinellifolium
Tobacco mosaic virus	TMV	L. peruvianum

Source: Charles M. Rick, "Germplasm Resources in the Wild Tomato Species", Acta Horticulturae, 190 (1986) pp. 39-47.

increase the vitamin content, reduce the pH level and make other improvements.[13] In addition, although the red fruited species are the major sources of genes used to modify tomato pigments, the green fruited species L. hirsutum and other green fruited species contain the Beta (B) gene which diverts most carotenoid synthesis to B-carotene. In addition, L. chmielewskii is the source of the ***Ip*** gene which intensifies pigment. The potential improvement in soluble solids from using wild germplasm is also much greater than can be obtained using standard varieties. For example, by backcrossing and selecting from L. chmielewskii, it has been possible to boost soluble solids by 40 percent. In addition, titraitable acidity has been greatly improved by using a gene from L. pimpinellifolium [Rick, 1986].

Wild germplasm also is a promising source of resistance to environmental stress. For example, L. cheesmanii which thrives on the shores of the Galapagos Islands two meters above high tide, survives in seawater whereas cultivated varieties die if seawater exceeds 50 percent. Another species Solanum pennellii, thrives in an extremely dry habitat in western Peru [Rick, 1978], while L. hirsutum species have been found to be resistant to both cold and drought [Garanko, 1991].

III.2.5. Breeding Objectives:

Increased yield and quality are the universal goals of most breeding programs. However, breeding for yield and quality alone is seldom an effective strategy since many aspects of the environment and the plant's physiology affect the eventual

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[13] Some examples of the sources of quality related traits include: sugars (soluble solids), titraitable acidity, earliness and high yielding attributes from L. pimpinellifolium. Drought resistance has been obtained from L. pennellii [Kalloo, 1991].

outcome.[14] Thus, breeders focus on how the individual genetic components of the production system contribute to yield and quality. In the case of yield, primary emphasis is placed on selecting for disease resistance, yield potential, nematode resistance, earliness, and growth habit [Tigchelaar, 1986]. To improve quality, breeders focus on color, soluble solids, viscosity, acidity and several other traits. Breeders hope to eventually develop varieties that have improved heat tolerance to expand the growing region and to extend the length of the season [May--personal communication].[15] However, each breeding program is specifically tailored to suit one or more processing objectives. For example, Campbell's breeding program focuses on the development of cold break varieties since over half of its pack consists of cold-break paste products [Jacobs--personal communication].[16]

Several different factors influence processing tomato breeding objectives in California. First, breeders must consider whether the processed product will be used for paste, juice, whole peel, or diced products. Second, they must consider where the tomatoes will be grown in the state. Some varieties have broad adaptability whereas other varieties are narrowly adaptable [George and Berry, 1992]. Varieties with

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[14] Heritability is defined as the proportion of phenotypic variation that is due to additive genetic variation. GxE interactions are defined as the inconsistent response of genotype (G) in a series of different environments (E). The uncontrolled variation that may influence the magnitude of heritability is predominately due to the GxE interaction. The GxE component represented only 9.7 percent of the estimated genetic variation of fruit size, but represented 24.3 and 31.3 percent of the genetic variation of earliness and total yield respectively [Pierce, 1991].

[15] It has been difficult for breeders to incorporate heat tolerance since it is controlled by several genes which are difficult to identify. In addition, it is difficult to screen for heat resistant varieties in the field because there is not always sufficient heat at flowering to perform adequate tests [Nichols--personal communication].

[16] Cold break tomato paste is processed at a lower temperature than hot break tomato paste.

broad adaptability are able to produce high yield and quality under a wide range of environmental stress conditions. This includes low and high temperatures, moisture deficiency, salinity and disease [Berry and Uddin, 1991]. As a result, in recent years plant breeders have emphasized the development of varieties that are able to tolerate environmental stress. Third, breeders must carefully consider the needs of processors that go beyond the final end-use of the raw product. They also must consider how the variety will affect the percentage of usable fruit, operating costs, processing plant flexibility and product consistency. For example, if a variety lacks firmness, the percentage of usable fruit drops. If the processor uses old equipment, a highly viscous variety will cause machinery breakdowns, cause delays and increase costs. Many paste processors desire high soluble solids since it tends to reduce processing costs while increasing case yield. On the other hand, whole peel processors prefer to use varieties that peel easily and are free of physiological disorders such as yellow shoulders [Schroeder, 1993].

III.3. Characteristics Desired by Growers and Processors:

III.3.1. Characteristics Desired by Growers:

Growers indicated that they attempt to select varieties that produce high yields, are resistant to diseases and nematodes, have excellent field holding, the appropriate vine size and maturity length, are heat and drought tolerant and are acceptable to canneries. Table 3.4 provides a list of growers' rankings of the importance of twenty-three selected genetic traits. The value of each listed trait varies somewhat from region to region due to different climatic and soil conditions and disease

Table 3.4. Grower Ranking of the Importance of Selected Genetic Traits at the Farm Level

Traits	Importance of Traits by Growing Region			
	Region I	Region II	Regions III-V	State
	----------Grower Ranking of Traits[a]----------			
Fruit Color	3.71	3.86	4.57	3.84
Fruit Shape	2.85	2.35	2.71	2.68
Vine Size	4.26	4.30	4.14	4.26
Canopy Type	4.19	4.05	4.00	4.13
Yield	4.93	5.00	5.00	4.96
Bacterial Speck Resistance	4.21	3.91	4.14	4.11
Black Mold Resistance	4.35	3.74	4.29	4.15
Fusarium Wilt Race II Resist.	4.37	3.74	4.14	4.15
Nematode Resistance	4.07	3.79	4.57	4.03
Days to Maturity	3.93	3.83	4.14	3.92
Field Holding	4.65	4.61	4.71	4.64
Viscosity	2.56	3.05	3.14	2.77
Soluble Solids (Brix)	3.66	3.61	3.14	3.59
Peelability	3.32	2.91	3.14	3.17
Fruit Firmness	4.63	4.21	4.71	4.50
No Yellow Shoulders	3.20	2.82	3.00	3.05
Stem Retention	3.27	3.09	3.43	3.23
Multi-use Potential	3.78	3.68	2.85	3.66
Fruit Setting Ability	4.85	4.83	4.85	4.85
Heat Tolerance	4.43	4.38	4.14	4.38
Drought Tolerance	3.44	3.23	3.57	3.39

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Growers ranked the importance of each trait from 1 to 5. A ranking of 5 indicates that the factor is very important while a ranking of 1 indicates that the factor is unimportant.

problems. For example, disease and nematode resistance are less important in Region II than in the other production regions. Grower cultural practices also have an effect on the value of each trait.

Black mold resistance is more important in the Delta region since the area is more humid and receives more rain than other growing regions [Petz--personal communication]. The OP variety 6203, which is planted in the southern portion of the San Joaquin Valley, cannot be grown successfully in the northern half of the valley since it is susceptible to Fusarium wilt race II [Nichols--personal communication]. Heat resistance is especially important in the case of tomatoes that are harvested after the twenty-fifth of July [Fabbri-personal communication]. Other traits, such as nematode resistance, are only needed in the infected portion of growers fields [Fawcett--personal communication].

Since growers are paid primarily on the basis of delivered tons, they are primarily concerned about yield enhancing traits. However, they are concerned also about quality since the price they receive is partly a function of several quality parameters, including mold content, worms, cracked and broken fruit and color. If growers fail to satisfy one or more quality standards, their net paid weight per ton is reduced by a set amount per infraction.[17] Processors also pay growers an incentive if they achieve high soluble solids, minimal limited-use and superior color. Even without incentives, many growers prefer to use varieties that satisfy processors' needs to increase the probability of obtaining future contracts [Turkovich--personal

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[17] For instance, suppose that a grower delivers 10 tons to an inspection station. If the worm content exceeds an upper tolerance, the grower may only be paid for 9.8 tons with .2 tons deducted as a penalty. If the quality is very poor the load will be rejected.

communication]. On the other hand, if certain traits have no effect on the price growers receive, they may not care whether they are important to the processor. In some cases, they may attempt to reduce the level of the characteristic, such as high soluble solids, since it affects yield.[18] One grower indicated that several years ago he earned soluble solids incentives between $6 per ton and $7 per ton since his soluble solids ranged between 7 percent and 8 percent. However, his average yield per acre was only 22 tons. In comparison, he earned more money on river ground where he produced 35 tons per acre and achieved average soluble solids of only 5 percent [Merwin--personal communication].

III.3.2. Characteristics Desired by Processors:

Processors are very concerned about the mix of characteristics they purchase since a product with poor color or some other quality defect is either not marketable or must be sold at a discount [Rivara--personal communication]. In addition, their customers demand that quality be the same from container to container. When they observe a decline in quality, they quickly switch to other suppliers [Pruett--personal communication]. Processors also are interested in a somewhat different set of characteristics than growers. The exact mix of characteristics demanded depends on the types of products they produce, their marketing strategies, the age and sophistication of their processing facilities and other factors.

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[18] When soluble solids increase they tend to depress yields and vice versa. However, due to varietal improvements over the past fifteen years, both yields and soluble solids have increased across the board [Stevens--personal communication].

For instance, processors are more interested in traits such as soluble solids, color, peelability and shape than growers, although growers are frequently paid an incentive to provide many of these traits. Processors also are more interested than growers in traits such as viscosity, stem retention (jointless pedicel), multi-use potential and physiological disorders since growers do not receive an incentive or deduction if these traits are lacking.[19] On the other hand, processors are less interested in high yield potential than growers since much of the tomato weight consists of water which must be partially boiled off to produce paste and other tomato products [Nichols--personal communication]. However, processors also are concerned also about yield since they must produce enough final product to satisfy their customers. In addition, their processing plants run more efficiently if they operate at or near capacity.[20]

Table 3.5 provides a list of grower rankings of twenty-three selected traits important to processors. Growers indicated that the most important processor traits in descending order are: soluble solids, peelability, fruit color, viscosity, fruit firmness, stem retention, multi-use potential, no yellow shoulders and field holding. The only important traits that overlap between processors and growers are fruit firmness and field holding.

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[19] The physiological disorders yellow shoulder and yellow eye (non-ripening areas) make it impossible to use the fruit for whole peel [Nichols--personal communication].

[20] It is more efficient for processors to run at full capacity for the entire season [Gill--personal communication]. However, higher freight and premium costs are incurred to obtain early and/or late tomatoes [Lomanto--personal communication]. For example, processors who obtain tomatoes from the Imperial Valley early in the season, pay as much as $75 per ton of raw tomatoes and $75 per ton for freight costs since most processing plants are located in the northern part of the state [Hirahara--personal communication].

Table 3.5. Grower Ranking of the Importance of Selected Genetic Traits at the Processor Level

Traits	Importance of Traits by Growing Region			
	Region I	Region II	Regions III-V	State
	----------Grower Ranking of Traits[a]----------			
Fruit Color	4.72	4.73	5.00	4.75
Fruit Shape	3.76	3.36	2.50	3.55
Vine Size	1.93	2.00	2.25	1.98
Canopy Type	2.17	2.09	2.25	2.16
Yield	2.69	3.09	3.50	2.86
Bacterial Speck	3.10	2.73	3.00	3.00
Black Mold Resistance	3.83	3.18	3.00	3.59
Fusarium Wilt Race II Resist.	3.45	3.09	2.75	3.29
Nematode Resistance	3.21	2.64	3.00	3.04
Days to Maturity	3.59	3.91	3.00	3.62
Field Holding	4.07	4.18	4.25	4.11
Viscosity	4.48	4.82	4.50	4.57
Soluble Solids	4.76	4.82	4.75	4.77
Peelability	4.79	4.82	4.50	4.77
Fruit Firmness	4.41	4.64	4.75	4.50
No Yellow Shoulders	4.38	4.36	4.00	4.34
Stem Retention	4.52	4.45	3.75	4.43
Multi-use Potential	4.38	4.55	4.25	4.41
Fruit Setting Ability	3.14	3.18	2.75	3.12
Heat Tolerance	3.14	3.09	2.50	3.07
Drought Tolerance	2.59	3.00	2.00	2.64

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Growers ranked the importance of each trait from 1 to 5. A ranking of 5 indicates that the factor is very important while a ranking of 1 indicates that the factor is unimportant.

Some traits are only important for paste production, others are only important for dice and whole peel products, while some characteristics such as fruit color are important for both sets of products. Several processors are interested in varieties with high viscosity to produce catsup since it affects their case yield. Other processors require low viscosity to prevent their machinery from becoming clogged [Fawcett--personal communication, Tigchelaar, 1986]. Since the quality and the number of tons of paste produced depends on the level of soluble solids, high soluble solids varieties are desired by many processors. The level of acidity is important since it affects flavor and the usability of the fruit.[21] Fruit with jointless pedicels are very important for whole peel processors since it can affect the taste and overall quality of the product. Fruit shape also is very important to whole peel packers since some consumers demand pear shaped tomatoes while blocky varieties tend to peel better and have other desirable attributes.[22] [Berry and Uddin, 1991]. Fruit color is an important determinant of the number of tomatoes needed to manufacture certain processed products [Stevens, 1986]. Lastly, varieties that can be used for either peel or dice products, are becoming more important due to the rapid growth of the salsa market.

Despite plant breeders considerable efforts, they have had only limited success improving fruit quality because of the complex interactions between the various

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[21] Campbell is the only seed company that breeds varieties to have low acidity [Kuehn--personal communication].

[22] It has been estimated that only one in five peeled tomatoes can be used in a whole peel pack while the rest are used to produce paste [Berry and Uddin, 1991]. Another important attribute of fruit shape concerns harvest damage. Elongated varieties tend to be more resistant than round varieties to fruit damage when harvested [Gould, 1992].

components of tomato fruit, plant and fruit characteristics and fruit composition. Genetic studies of gross traits such as total acidity and total solids often indicate multi-genic control. Thus, to breed genetic improvements that depend on a large number of genes, it is necessary to investigate each component of the desirable trait separately [Gould, 1992]. In addition, the manipulation of one trait sometimes has an adverse impact on one or more other important traits. For example, when new varieties were developed to enable tomatoes to be harvested with mechanical harvesters, the change in the leaf/fruit ratio reduced the level of soluble solids while the ratio of insoluble solids to soluble solids was greatly increased [Stevens and Rick, 1986].[23] There also is a negative correlation between the level of soluble solids and insoluble solids. Thus, it is difficult to produce fruit that has both taste and high viscosity [Rudich and Luchinsky, 1987].

III.4. Breeding for Characteristics:

III.4.1. Breeding for Yield:

Growers indicated that the most important tomato characteristic is yield potential since their profits are primarily a function of the number of tons they produce.[24] Over the past thirty years the average yield of processing tomatoes

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[23] However, continued breeding using germplasm from wild species resulted in varieties with soluble solids equal to or greater than the old hand-harvested varieties [Stevens, 1986].

[24] Several years ago CTGA conducted a study of California processing tomato growers. It found that growers need to produce between 32 and 34 tons per acre to break even. An informal survey of 15 growers indicated that between 25 and 35 tons are needed to break even. Some of the variation is due to differences in farm sizes, soil quality, cultural practices, weather and land payment strategies. One grower indicated that for rental land he breaks even by producing 36 tons per acre while on his own land he breaks even by producing 34 tons. Distance from the processing plant is also a factor since deductions tend to increase with distance--although processors pay for shipping [Woolf--personal

produced in California has increased from 21 tons to over 33 tons per acre. The increased yield is due to improvements in crop culture, management practices and genetic improvements. The most notable genetic improvement was the introduction of hybrid varieties, which due to heterosis, have helped to increase yields between 5 and 10 tons per acre. However, there is a wide range in the number of tons that growers produce per acre. Some growers produce between 20 and 25 tons per acre while others produce as much as 60 tons per acre. One grower has managed to produce 40 tons per acre for the past fifteen years [May--personal communication]. Growers estimated that during 1995, yields ranged between 18 and 61.7 tons per acre with a mean of 35.8 tons and a standard deviation of 6.5 tons (Table 3.6).[25]

There exists significant yield variation among production regions, among farms in the same region, and within the same farm. For example, historically yields have been higher in Region II than Region I since the region has fewer disease problems and has been farmed less intensively over the past twenty years. The inter-farm variation is largely due to differences in soil quality, weather conditions, cultural practices, and the varieties planted. In addition, there is a fairly wide, albeit narrower range of yields, achieved intra-farm which is due to the varieties selected, soil variation, harvest schedule and how growers choose to match soils with varieties. Growers occasionally trade-off high yielding varieties for varieties that hold better, are disease resistant, and are stronger under adverse conditions [Fawcett--personal

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communication].

[25] Their estimate of average state-wide yield was somewhat higher than the state-wide average yield obtained from the California Agricultural Statistics Service (33.5 tons).

Table 3.6. Grower Estimates of the Average Yields of Processing Tomatoes Harvested During 1995, by Region

Region	Yield Data			
	Average	Lowest Yield	Highest Yield	Standard Deviation
	----------Tons per Acre----------			
Region I	32.91	18.0	52.0	6.0
Region II	37.94	26.0	61.7	6.8
Region III	40.86	25.0	53.0	7.6
State	35.79	18.0	61.7	6.5

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

communication]. This is especially important if the grower has poor soil [Robertson--personal communication].[26] Also, the intra-farm yields can vary tremendously from year to year. One grower commented that even if he performs all of his cultural practices correctly (i.e. fertilize, cultivate, irrigate, etc.) his yields vary between 25 and 45 tons per acre from one year to the next due to the variability in seasonal weather conditions [Yerxa--personal communication].[27]

Plant breeding also has helped to increase yields via improved disease and nematode resistance, field holding, environmental stress tolerance, greater flexibility in maturity and harvesting and other genetic improvements. Since yields would be significantly lower without these genetic improvements, growers and processors are unwilling to adopt new varieties that lack one or more of the traits. The impact of each trait on yield varies depending on the part of the state. For example, during the 1970s yields in Yolo and San Joaquin counties were adversely affected by root rot diseases. In contrast, yields increased in Fresno county since root rot is not a problem in the region [Stevens, 1986].

Processors discourage growers from planting varieties that are designed to produce high yields at the expense of soluble solids since they reduce the case yield of the processing plant while increasing production costs [Angell--personal

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[26] Asgrow Seed Company stresses the development of varieties that have a strong root system so they will perform well in both marginal and good soils. Plants with strong roots are especially important in areas that have either a salt problem or heavy soils [Angell--personal communication].

[27] Growers also lose yield if they plant tomatoes back to back on the same piece of ground. Growers who plant two consecutive tomato crops on the same ground, usually lose between 3 and 5 tons per acre [Lomanto--personal communication].

communication].[28] Oftentimes, processors allow growers to plant some varieties that are high yielding as long as they plant other lower yielding varieties that provide more of the type of characteristics demanded by processors [Turkovich--personal communication]. Other processors, like Campbell, attempt to satisfy both groups by breeding varieties that combine reasonably high yields with desirable processor attributes [Kuehn--personal communication]. Although processors assess growers deductions for poor quality, growers frequently plant high yielding varieties since the higher yields more than compensate for processor deductions [Robertson--personal communication].

III.4.2. Breeding for Disease Resistance:

For many years growers have attempted to control diseases with pesticides, especially fungicides. However, since pesticides are expensive and ineffective against some pathogens, and since the public is concerned about pesticide residues on food, the processing tomato industry has attempted to use genetic based resistance whenever feasible. As government restrictions on the use of pesticides become more stringent, the need for genetic resistance will increase. For the most part, disease resistant traits transferred into commercial varieties have been conferred by a single dominant gene. In those cases where disease resistance appears to be inherited in an oligogenic or multi-genic fashion, there have been far fewer successful transfers of disease resistant

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[28] If a grower sends a 25 ton load to the cannery the processor may only be able to use 60 percent--that is what is meant by case yield. Processors save a tremendous amount of money by increasing the case yield to 70 percent. Thus, if processors had to choose between a variety that yielded 1000 pounds of paste versus one that yielded only 500 pounds of paste they would choose the variety that has a higher recovery [Fawcett--personal communication].

characteristics to commercial varieties. However, even in those cases where single gene resistance has been achieved, the diseases in some cases have mutated to overcome the resistance. For example, single gene resistance has been short lived for the leaf mold pathogen Fulvia fuva [Watterson, 1986]. In addition, in some parts of the world the *I* gene has become susceptible to race II of Fusarium wilt [Gould, 1992].[29]

Disease resistance is more important to growers than processors since it can wipe out a grower's production, while processors obtain the tomatoes they need from many different sources [Welty--personal communication]. However, processors also are concerned about diseases because they affect quality, especially in the case of whole peel tomatoes [Gill--personal communication], and because they reduce the number of tons available to process. If disease problems are widespread, processors may not be able to purchase enough raw tomatoes to run their plants efficiently, and they may not be able to meet the needs of their customers. Processors also prefer to use varieties with disease resistance to minimize the use of pesticides [Kuehn--personal communication]. The need for disease resistance depends on weather conditions, soil types and the part of the state where the tomatoes are grown. For example, although resistance to Fusarium wilt race II is very important in the

[29] The tomato industry is highly dependent on a few genes that confer disease resistance. Thus, it is imperative that alternative genes be located and backcrossed into cultivated varieties to prevent diseases from mutating and overcoming the resistant genes. The uniformity of tomato varieties leaves open the possibility of the crop suffering a disaster similar to the epidemic that befell the corn crop after the introduction of a new race of Southern corn leaf blight [Gould, 1992].

northern part of California, it is not important in the southern part of the state [Hirahara--personal communication].[30]

Over 200 diseases affect tomato production and can result in yield losses as high as 95 percent [Lukyanenko, 1991]. The pathogens that affect processing tomato production in California are bacteria, fungi, and viruses. Bacteria and fungi are only destructive when temperature and moisture are favorable to their development. Since tomatoes are grown under a wide range of environmental conditions, a disease that causes problems in one area may be almost unknown in another [Gould, 1992]. For example, when ambient temperatures are high, Fusarium wilt causes damage while Bacterial wilt and Stem rot are seldom found [Watterson, 1986]. Diseases are either soil borne or airborne, and in the case of viruses are either spread by machinery or insects. The soil borne diseases in California are caused by fungi. Phytophthora root rot, damping-off, Pythium ripe fruit rot and buckeye rot are among the most damaging. Two of the more important, Fusarium wilt and Verticillium wilt, are largely controlled by resistant varieties.[31] Before Fusarium wilt resistant varieties were introduced in 1941 (Pan American cultivar), growers were constantly forced to abandon farmland that was infected with the disease. Some parts of the Eastern U.S.

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[30] As a result, some varieties only have resistance to Fusarium wilt race I [Brown--personal communication].

[31] Verticillium wilt is caused by Verticillium albo-atrum and V. dahliae. In field tests race I reduced yields between 40 and 47 percent while race II reduced yields by 19-31.2 percent. A single dominant gene resistant to Verticillium wilt was found in 1932 in L. pimpinellifolium and was designated *Ve*. The gene confers resistance to most strains of Verticillium wilt although one strain is causing tomato losses in some areas. Fusarium wilt, Fusarium oxysporum F. sp. lycopersici Sacc., causes yield losses between 10 and 50 percent in many parts of the world. Resistance to Fusarium race I was found in L. pimpinellifolium in 1940 (called the *I-1* gene). Resistance to race II was found in L. pimpinellifolium in 1945 (*I-2*) [Lukyaneko, 1991].

were entirely lost to commercial tomato production. Some diseases are caused by environmental stress, genetic defects, and/or exposure to toxic substances. The most common of these in California is sunscald [University of California, 1985].

Above ground diseases which include Black mold, Bacterial speck and Gray mold also cause significant losses in some areas.[32] Diseases such as Septoria leaf spot and Bacterial speck have ruined crops in temperate regions [Watterson, 1986]. Black mold can be a particularly severe problem in the central part of the state since the fruit tends to be harvested late in the season when the days are short and the nights are cool; and since there is an increased likelihood of rain and dew forming on the plants [Mullen--personal communication].[33] Growers prefer to use mold resistant varieties in these areas. Bacterial diseases also cause problems in some growing regions. The bacterial disease that is currently causing the most severe problems is Bacterial speck which infects plants during wet springs when the plants are still in their juvenile stage [Timothy--personal communication].[34] Bacterial speck became a major problem after the introduction of hybrids enabled growers to move their harvest time-tables forward. Before the development of hybrids most growers harvested their tomatoes in September. Now, they can start harvesting during the early part of July

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[32] There is currently no genetic resistance available to control black mold while gray mold is primarily a post harvest rot problem of fresh tomatoes. Bacterial speck occurs mostly in early plantings when the tomatoes are exposed to rain, heavy dew or sprinkler irrigation [University of California, 1985]. Resistance to Bacterial speck (Pseudomonas syringae pv. tomato) has been found in many wild species accessions including L. hirsutum, L. peruvianum, L. glandulosum, and L. pimpinellofolium [Lukyaneko, 1991].

[33] This includes Stanislaus, southern Yolo, the central coast and southern Sacramento [Mullen--personal communication].

[34] Most growers plant their fields during the months of January-March which is also the most likely time of the year to receive rain [Fabbri--personal communication].

[Fabbri--personal communication]. As a result, Bacterial speck has only been a major problem for the past few years [Brown--personal communication]. However, new varieties with Bacterial speck resistance give fairly good protection against the disease [Merwin--personal communication].

III.4.3. Breeding for Nematode Resistance:

Nematodes are a microscopic worm like animal. Although over sixty species of nematodes attack tomatoes, the most destructive is the root-knot nematode (Meloidogyne incognita). It can significantly reduce tomato yields and in some cases destroy the crop. Even in an ideal environment, it can cause yield losses of 50 percent or more [Berlinger, 1986]. Although they are found in a wide range of soils, nematodes cause most of their damage to roots in sandy soils and can significantly reduce plant growth and yield. There is also some evidence that damage by nematodes causes tomato plants to become susceptible to diseases they normally resist such as Fusarium wilt [Fassuliotis, 1991].

For almost forty years, nematodes were controlled with chemical fumigants such as methyl bromide and nematicides such as carbofuran. Until recently, growers were able to control nematodes with a now banned pesticide called Telon [Kuehn--personal communication].[35] When it was removed from the market, seed producers

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[35] Growers with nematode problems used to spend $60 to $70 per acre on Telon and on application costs. Thus, although hybrid seed which contains the resistant gene is much more expensive than OPs, the cost of the chemical treatment should be subtracted from the seed cost [Fabbri--personal communication].

and growers replaced it with genetically resistant varieties and cultural practices.[36] Resistance to nematodes, which was found in many tested accessions of L. peruvianum (PI 128657), is controlled by a single dominant gene (*Mi*) located on chromosome 6. The gene was transferred to L. esculentum using embryo culture [Stevens and Rick, 1986]. However, there were many hurdles to cross before a suitable commercial variety could be developed. The first varieties developed via repeated backcrosses were small fruited, late maturing, and contained concentric cracks. After thirty years of research, a variety called Anahu was released in 1958. It was developed from a cross of L. esculentum Michigan State Forcing and L. peruvianum and has since served as a parent for F_1 hybrids.[37] However, the resistance breaks down at temperatures above 29°C (82°F) and nematode populations exposed to the *Mi* gene through monoculture practices have increased their resistance with each passing generation [Fassuliotis, 1991].

Since the number of acres that are infested with nematodes continues to grow each year, virtually all new varieties contain nematode resistance [Angell--personal communication].[38] However, farms that have nematodes do not necessarily have them on all the acreage and they are not a problem in heavy soils [Turkovich--personal communication]. In addition, the newer production regions such as Fresno

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[36] There are also a number of cultural strategies employed by growers to reduce nematode damage--such as by using a rotation of crops that are able to resist nematodes [Berlinger, 1987].

[37] One drawback of older nematode varieties is that they have poor field holding [Lomanto--personal communication]. However, the newer varieties hold just as well as the varieties without nematode resistance. For example, Heinz 8892 is nematode resistant and has excellent color and very low deductions [May--personal communication].

[38] One of the reasons the most popular varieties (BOS 3155 and Brigade) will eventually be replaced is because they lack nematode resistance [Angell--personal communication].

county, have fewer nematode problems since they have had less contamination from machinery and other sources [Hirahara--personal communication].[39]

III.4.4. Breeding for Field Holding:

Field holding is important because it enables growers to leave their crops unharvested in the field for an extended period of time without having to worry about the crops rotting. This is especially important in the Central Valley where temperatures sometimes reach 105 degrees fahrenheit [Angell--personal communication]. The length of time a variety can be held in the field is largely a function of its ability to resist fruit cracking, the severity of which depends on local climatic conditions. Crack resistance is controlled by several genes which are available in a number of varieties. Field holding also is influenced by several fruit rots, in particular anthracnose which is caused by the fungus Colletotricum [Berry and Uddin, 1991].

Field holding became very important to growers during the 1970s when processors added a limited-use (cracked and broken) deduction category. Growers were allowed to plant undesirable varieties but suffered deductions as high as 25 percent if the fruit was too soft [May--personal communication]. Field holding has become progressively more important since growers are harvesting record crops and planting more acreage--both of which increase the harvest time while taxing the capacity of the canneries [Jacobs--personal communication]. As a result, it is not

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[39] Some growers are able to minimize the nematode problem by using a crop rotation that is nematode resistant [Fawcett--personal communication].

unusual for processors to ask growers to delay shipment of a portion of their harvest due to processing plant capacity constraints or some other problem.[40] For example, a processor may allow a grower to only deliver twenty loads instead of the contracted fifty loads. The grower also may need to delay the harvest of one field to harvest a different field which is on the verge of "going over the hill". If some varieties are not harvested immediately after ripening, they become soft and mushy and are rendered useless. Thus, if a grower plants one portion of his field with tomatoes that have good color but poor holding, and the rest with varieties that hold longer, the grower will first harvest the good color tomatoes [Brown--personal communication].

Field holding was especially important during 1995 when rain forced many growers to plant their crops late which caused more varieties than normal to reach maturity at the same time. Processors also prefer varieties that hold well if shipments are staggered due to poor weather or some other unforeseen exigency [Lomanto--personal communication]. One of the reasons BOS 3155 is the number one variety is because it holds extremely well. Growers can walk away from BOS 3155 for a week or longer and suffer minimal deductions [Stevens--personal communication].[41]

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[40] Canneries start to receive their deliveries of raw tomatoes slowly. However, the number of loads delivered quickly reaches a peak and stays there for many weeks. Processors attempt to design a uniform delivery schedule to avoid placing growers on quotas which can cause high field losses due to high summer temperatures [Nichols--personal communication].

[41] When one grower in the Fresno area left BOS 3155 in the field for 30 days past maturity limited-use only increased from .5 to 1 percent. During the next 7 to 8 days it took to harvest the field, limited-use jumped to 4 or 5 percent. Any other variety would have completely rotted in the fields after only fifteen to twenty days [Herringer--personal communication].

III.4.5. Breeding for Stress Tolerance:

Since the nine species of tomatoes occupy a wide range of ecological niches, substantial variation exists in the ability of tomato varieties to tolerate environmental stress. Some stress tolerance traits have been backcrossed into commercial varieties. For example, significant progress has been made to develop tomato varieties which set under a wide range of temperature extremes and which resist rain induced fruit cracking. Concentrated fruit set is particularly important since the crop is harvested only one time by the harvester.[42] Accessions of L. hirsutum, L. chilense and S. lycopersicoides may one day enable breeders to develop tomato varieties with increased resistance to chilling temperatures (0°C to 10°C) [Stevens, 1986]. However, there are many other stress tolerance traits such as salt tolerance which have been identified in L. cheesmanii, L. pennellii and L. peruvianum, and drought tolerance found in L. pennellii, L. chilense and a few accessions of L. pimpinellifolium which have not yet been widely utilized [Kalloo, 1991, Tigchelaar, 1990].[43]

The best source for drought resistance appears to be L. pennellii due to a much larger root structure than drought susceptible varieties and an ability to hold

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[42] The most serious effect of high temperatures is a reduction or prevention of fruit set. When temperatures exceed 35°C (95°F) the germination of seeds, seedling growth, flowering fruit set and ripening are adversely affected. In addition, the fruit size is reduced. In contrast, when temperatures fall below 12°C (53.6°F) plant growth, fruit set and overall plant development are adversely affected [Kalloo, 1991]. If varieties could be developed that tolerate colder temperatures, they would be earlier, more adaptable, require less irrigation and produce higher yields [Stevens and Rick, 1986]. Low and high temperatures also have been noted to adversely affect fruit color and firmness [Grierson and Kader, 1987]. Tolerance to high temperatures has been noted in L. esculentum var. cerasiforme, L. pimpinellifolium and L. cheesmanii while low chilling tolerance has been observed in L. hirsutum and high altitude accessions of L. chilense [Kalloo, 1991, Rick, 1986].

[43] When the salt level is too high, yield is drastically curtailed due to a reduction in fruit size [Kalloo, 1991].

water during periods of prolonged drought. Based on field trial results of a hybrid of S. pennellii and L. esculentum, it may be possible to eventually transfer the trait into commercial varieties. In contrast, traits have been identified also to protect tomato plants in situations where there is too much water. Although excess water may increase yields, fruit quality declines as reflected in reduced soluble solids [Rudich and Luchinsky, 1987].

Physiological disorders such as solar injury, fruit cracking and uneven fruit ripening also are caused by environmental stress. In the case of solar injury, if the ambient temperature remains above 30°C (86°F) for a prolonged time period, the affected part of the fruit becomes yellowish. The disorder can be reduced by using varieties that produce sufficient foliage cover to shade the fruit. Fruit cracking is affected by soil moisture, rainfall, high temperatures, and dew. The use of crack resistant varieties can minimize losses associated with this disorder [Grierson and Kader, 1986]. However, various studies have indicated that it is difficult to develop crack resistant varieties since it is a quantitative trait which is conferred by many genes. High temperatures and light contribute to uneven fruit ripening. The firm fruited varieties developed for mechanical harvesting have a tendency to develop areas of white tissue. In general, there are distinct differences among tomato genotypes in terms of susceptibility to ripening disorders which plant breeders have had varying degrees of success controlling [Stevens and Rick, 1986].

III.4.6. Breeding for Harvest Efficiency:

The harvest date for each load of tomatoes is specified in the contracted agreements reached between growers and processors. Under optimal growing conditions, the best time to harvest the fruit is when 90 percent is red or pink. Varieties that hold well in the field can be harvested within five to ten days after the optimum has been reached without suffering any appreciable weight loss. If the harvest is delayed beyond this point, additional mold will develop and the fruit weight will fall. However, as long as the fruit is harvested within twenty-five to thirty-five days after full ripeness, 90 to 95 percent of the fruit can be used for processing.

The harvest in California begins in the desert valleys in mid-June and ends in the southern coastal areas in November [Sims, 1992]. Each grower's harvest schedule is partly based on when the crop was planted and the maturity length of the variety. Varieties require anywhere from 100 to 135 days to mature, and the fruit needs between forty and sixty days to ripen after the first flowers open seven to eight weeks after seeding [Tigchelaar, 1986, Rick, 1978]. However, since each field is only harvested one time, the grower's harvest schedule is also partly determined by how much he can physically harvest in one day and how much production the processing plant is able to take at any one time [Geisenberg and Stewart, 1986].

Growers have the option of planting either early, mid-season, or late maturing varieties.[44] The maturity length is very important to growers for several reasons.[45]

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[44] Hybrids made possible the development of early and late maturing varieties. Most OP varieties mature in 120 days while some hybrids can be harvested in 105 days and Peto 31 can actually be harvested in only 100 days. Unfortunately, since Peto 31 has poor canning characteristics, processors removed it from their approved variety lists [Yerxa--personal communication].

First, using different maturity lengths allows growers to spread out their harvest which reduces the probability of the crop rotting in the field due to processor constraints [Lomanto--personal communication]. Second, if a natural disaster destroys the crop early in the season, the grower may be able to salvage the season by replacing a long maturing variety with one that matures much faster [Fawcett--personal communication].[46] Third, large growers plant varieties that mature at different times to maximize the use of their harvesters. Fourth, using varieties with different maturity lengths enables growers to deliver their crops to processors without having to hold the tomatoes in the field due to capacity constraints at any one cannery [Gill--personal communication].

Fifth, using short maturing varieties enables many growers to harvest their crops before the latter part of the season when the risk of losing the tomatoes to diseases such as Black mold increases significantly due to short days, rainfall and dew formation [Mullen--personal communication]. This is more important in the northern growing regions since the south finishes its harvest much earlier [Yerxa--personal communication]. Sixth, some parts of the state lack sufficient heat units to produce high quality fruit late in the season [Merwin--personal communication]. Seventh, varieties that remain in the field a shorter time are less likely to suffer damage from

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removed it from their approved variety lists [Yerxa--personal communication].

[45] Tomato fruit maturity depends on qualitative and quantitative changes in their carotenoid composition. If for example, the temperature is above 30°C (86°F), the lycopene level will be greatly reduced which is an important component of red-fruited tomatoes [Chalukova and Manuelyan, 1991].

[46] Early maturing varieties were particularly important during the 1995 crop season since heavy rains prevented growers in many areas from planting their crop for as long as six weeks. Seed companies were overwhelmed with calls for early maturing varieties [Angell--personal communication].

rain, heat, insects, or diseases [Merwin--personal communication]. Eighth, a shorter maturing variety requires less water which is very expensive in some parts of the state [Hirahara--personal communication].[47]

Machine harvesting also has created the need for varieties that mature at different times (particularly early maturing varieties). Crop delivery patterns peak at a higher production level for single-pick harvests than multi-pick harvests which can create gluts and inefficiencies at the processing plants [Berry and Uddin, 1991]. Varieties that mature at different times also extend and makes more manageable growers' harvest operations.

Since processors have invested a considerable amount of money in factory equipment, they try to spread out the harvest season for as long as possible. Thus, they prefer to purchase tomatoes from across the state and select varieties that mature at different times. Processors use early maturing varieties because they enable the canneries to start operating somewhat earlier than in the past. They purchase early varieties although they may not earn any profits due to high grower premiums and the high cost of shipping tomatoes from the Imperial Valley to canneries in the Stockton area. However, purchasing early varieties spreads their fixed costs over more units and it helps them protect their market shares if they are low on inventory [Angell--personal communication].

Not all processors accept early maturing varieties since the fruit generally has poor color and low solids. Processors may prefer to wait ten days when higher

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[47] Although early varieties have certain advantages, they are usually softer, not as strong, and usually do not produce as much tonnage [Fawcett--personal communication].

quality tomatoes start to be harvested [Woolf--personal communication]. Processors also attempt to stretch out the other end of the season by offering premiums as high as $15 per ton for varieties that are harvested during October. The high premiums are necessary since the risk of losing the crop to mold or heavy rains is much greater [Pruett--personal communication].

III.4.7. Breeding for Soluble Solids:

A primary determinant of tomato flavor is the ratio of sugar to acids.[48] Thus, paste derived products require a certain percentage of soluble solids, which is mostly sugar, to achieve a tomato like flavor.[49] Hence, the production of paste-based tomato products largely depends on the percentage of soluble solids contained within the raw product. Raw tomatoes typically contain between 4 and 7 percent natural tomato soluble solids (NTSS) [Pruett, Nichols--personal communication].[50] To produce paste, processors boil the tomatoes until the NTSS ranges between 28 and 32 percent. The NTSS depends on the type of paste demanded by wholesalers and remanufacturing facilities. A .1 percent increase in soluble solids reduces the cost of

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[48] There is tremendous variation among tomato species for pH and titraitable acidity. In a study of 250 tomato accessions, the pH ranged between 4.26 and 4.82 for the L. esculentum accessions and the percentage of citric acid ranged between .4 and .91 percent [Stevens and Rick, 1986]. L. pimpinellifolium reportedly has the highest levels of titraitable acidity; twice the average tomato level for citrate and three times for malate [Berry and Uddin, 1991].

[49] Tomato paste, as defined in the Standard of Identity for Tomato Paste (21 CFR 155.191) issued pursuant to the Federal Food, Drug and Cosmetic Act, contains not less than 24 percent of natural tomato soluble solids [Gould, 1992].

[50] The major components of soluble solids are the reducing sugars glucose and fructose which comprise approximately 65 percent of the soluble solids. The remaining soluble solids are composed of organic acids, lipids, minerals, pigments, volatiles and other substances [Berry and Uddin, 1991].

producing paste between $5 and $10 per ton since less energy is required to remove excess water [Pruett, Nichols, Rufer--personal communication].[51] Many concentrated processed tomato products are manufactured with solids in excess of 40 percent [Gould, 1992].

The importance of soluble solids varies from one processor to the next, depending on the mix of final and intermediate products they produce. However, there are two primary reasons why processors place less emphasis on selecting high soluble solids varieties than they did in the past. First, most of the varieties sold today have been bred to produce significantly higher soluble solids than the varieties produced thirty years ago. Second, there is a tremendous demand for raw product and higher viscosity. The increased demand has shifted processors' emphasis toward higher yielding varieties with higher viscosity and somewhat lower soluble solids [Mullen-personal communication].[52]

Wild species contain a wide range of soluble solids. The soluble solids of L. pimpinellifolium ranges between 4.9 and 9.2 percent, the soluble solids of L chmielewskii is approximately 10 percent, while L. cheesmanii contains between 10 and 15 percent soluble solids. By successively backcrossing the high soluble solids characteristic of L. chmielewskii into L. esculentum, the soluble solids of commercial varieties have been significantly improved. However, soluble solids tends to reduce

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[51] A cannery that processes 1 million tons per year can save $1 million by increasing the soluble solids by .1 percent. This occurs since the amount of sugar the varieties start out with determines how long it must be cooked to reach either 28 degrees brix (soluble solids), 30 degrees brix or 32 degrees brix [Jacobs--personal communication].

[52] Processing costs become progressively more expensive as the viscosity level increases because soluble solids is inversely related to viscosity. Thus, it costs more to produce a product that has 5 bostwick (viscosity) than a product that has 4 bostwick [Rufer--personal communication].

the yield of processing tomatoes since it is associated with large indeterminate vines of low fruit to leaf ratio, dispersed fruit set, late maturity and small fruit size [Berry and Uddin, 1991]. Unless the negative relationship can be overcome, high soluble solids are of little practical value since high yield is considered to be more important [Stevens and Rick, 1986]. As a result, commercial processing tomato varieties represent a compromise between yield potential and soluble solids. This is reflected in the soluble solids of commercial varieties which range between 4.4 and 5.7 percent [Tigchelaar, 1990].

Although the soluble solids level is largely controlled by genetics, it is also influenced by grower cultural practices and environmental conditions. To some extent, growers are able to increase or decrease the solids level by decreasing or increasing the amount of irrigation water respectively late in the season. In addition, different climatic and soil conditions affect the soluble solids level [Woolf--personal communication]. In some cases soluble solids vary by .2 to .3 percent within the same field [Timothy--personal communication].

III.4.8. Breeding for Viscosity:

Tomato viscosity (consistency) is defined as the resistance offered by a tomato's fluid relative to the motion of its parts [Gould, 1992].[53] It is a function of the percentage of insoluble solids (which consists of proteins, pectins, cellulose and

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[53] Several ways are available to measure viscosity potential. Using the acid efflux method, 2 kg of fully mature fruit obtained from variety trials is blended in 30 ml of concentrated HCl to inactivate pectin enzymes. After passing the resulting mix through a seed and skin extractor, the resulting juice is deaerated under vacuum for three minutes. The flow rate is then measured through a standard viscometer which is a measure of viscosity [Tigchelaar, 1986].

polysaccharides) contained within the tomato [Berry and Uddin, 1991]. Unlike soluble solids which remain relatively constant throughout fruit maturation, viscosity declines dramatically during the ripening process. However, since there are large differences in the viscosity potential of commercial varieties, there is still room for improvement. For example, breeding of firm-fruited varieties has significantly increased the thickness of sauces and catsup since it reconstitutes into thicker products [Berry and Uddin, 1991]. It also has been found that slow ripening inbreds and F_1 hybrids possessing the non-ripening ***nor*** gene, exhibit delayed pectin degradation and retain consistency much longer than normal ripening varieties [Tigchelaar, 1990].

Viscosity is an extremely important processing tomato quality since it frequently determines consumer acceptance of various tomato products--including catsup, tomato paste, tomato juice and tomato sauces. It also affects processor costs since it determines the number of tons needed to produce viscosity dependent tomato products [Gould, 1992]. During the past several years, viscosity has become much more important since consumers now demand thicker sauces and paste than before [Nichols--personal communication]. In addition, some processors such as Heinz, prefer high viscosity varieties since they are needed to produce high quality catsup [Turkovich--personal communication].[54] As a result, processors have shifted toward new high viscosity varieties such as Heinz 8773, and away from the Ferry Morse variety FMX 785, which has high solids but low viscosity [Kennedy--personal

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[54] Many of the processors have their own labs which they use to test different varieties for bostwick (viscosity) at various locations throughout the season. The Processing Tomato Advisory Board (PTAB) does not collect this information [Rufer--personal communication].

communication].[55] Many growers prefer varieties with higher viscosity since they tend to produce more tons per acre, are hardier and hold better than varieties with high soluble solids [Woolf--personal communication].

III.4.9. Breeding for Color:

Processors are very concerned about fruit color since it affects consumer acceptance of their products and the price they receive.[56] The fruit color and color uniformity are especially important for canned whole tomatoes since consumers are willing to pay a premium for fruit with a redder color [Berry and Uddin, 1991]. Processors also tend to receive a higher price for paste that has a bright red color [May--personal communication]. Although color is important, most processors do not pay growers an incentive for having redder tomatoes since it is a genetically controlled characteristic [Fawcett--personal communication]. However, fruit color is important to tomato growers since loads are rejected if the color fails to achieve minimum standards.

The flesh color of tomatoes is mainly determined by the content of carotenoid pigments--the most important of which are lycopene, which comprises approximately 83 percent of all the pigments, and B-carotene [Gould, 1992, Chalukova and

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[55] Most, if not all, of the varieties developed by Heinz have low soluble solids, high viscosity, high yield and excellent color--which are ideally suited to manufacture catsup. Although processors do not add sugar to paste, they are allowed to add up to 2 percent dextrose to catsup to bring it up to standard. Heinz has determined that it is cheaper to add sugar than it is to buy varieties with high soluble solids [Angell--personal communication].

[56] The color of tomatoes is measured at the inspection stations. The lower the comminuted color reading the higher the red color. If the reading goes above thirty-nine the fruit is rejected [Brown--personal communication].

Manuelyan, 1991]. Many genes have been identified that affect fruit color--in particular the crimson (*og^c*) and the high-pigment (*hp*) genes.[57] Since both genes are simply inherited, it is easy to backcross them into existing varieties. However, the *og^c* gene increases lycopene (the high pigment conditioning intensity of tomato red fruit) at the expense of B-carotene, which reduces the nutritive value of the fruit since the level of vitamin A is lowered.[58] In contrast, the *hp* gene increases total fruit carotenoids which results in excellent color and improved vitamin A levels. However, it also results in slower germination and growth, and premature defoliation [Tigchelaar, 1986]. Although it has been found that a combination of both the *hp* and *og^c* genes reverses the adverse effects of the *og^c* gene when used alone, and results in very high levels of lycopene, plant breeders are still working to overcome the negative impacts of the *hp* gene on plant performance [Berry and Uddin, 1991, Gould, 1992].

III.4.10. Importance of Multi-use Potential:

Processing tomatoes are used to produce one of five primary products: paste, whole peel, diced tomatoes, sliced tomatoes and sauces (product). Over 70 percent of

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[57] Wild species have also been identified as having genes that may be useful to enhance tomato color. For example, L. hirsutum and other green fruited species, contain the *B* gene which diverts most carotenoid synthesis to B-carotene, while L. chmielewskii is a source of the pigment intensifier gene *lp* [Rick, 1986].

[58] Carotenoid pigments are the only source of vitamin A for mammals. Beta-carotene has the highest vitamin A activity. Although lycopene has no vitamin A activity, it increases the amount of vitamin A available to the body by protecting it from oxidating decomposition in the intestines. It may also help protect B-carotene during fruit storage and processing [Chalukova and Manuelyan, 1991].

the harvest is used to produce paste [Rivara--personal communication].[59] This partly occurs because a large percentage of the tomatoes intended for whole peel and dice packs fail to pass quality standards established by individual canneries. As a result, processors encourage growers to plant multi-use varieties that can be used to produce either high quality paste or a peel/dice product. Many growers also prefer multi-use varieties since they increase the odds of finding a buyer for their excess production.[60] Consequently, multi-use varieties dominate the seed market [Stevens--personal communication].

The first popular multi-use hybrid variety was Brigade which was introduced by the Asgrow Seed Company. This was followed several years later by BOS 3155 which is produced by Orsetti Seed Company. Although neither of these varieties have the highest yield, soluble solids and viscosity, they are excellent for either peeling or paste production [May--personal communication]. The flexibility of the varieties is especially important for a multi-product processor like Tri-Valley [Jacobs--personal communication].

III.4.11. Importance of Vine Size:

Growers select varieties partly based on the type of row planting system used--either single or double row--since each type of row system requires a different vine

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[59] Diced tomatoes have become a very important product since they are a key component of salsa. Campbell recently spent over $1 billion to buy the company that produces Pace salsa.

[60] Although there is tremendous value added to peeling tomatoes, growers are not paid an incentive to plant whole peel varieties [Mast--personal communication].

size. Vines can be large (indeterminate), medium, or small (determinate).[61] If the grower prefers to plant a single row he is more likely to select large vined varieties, while growers who prefer to plant double rows are more likely to select small vined varieties [Kennedy--personal communication]. However, there is some debate regarding which method is the most efficient, exposes the grower to the lowest risk and saves the most money on seed and other expenses.

Some growers who plant single rows believe they save as much as $200 per acre on inputs including: seed, hoeing labor, pesticides, vine training, and cultivation [Yerxa--personal communication].[62] They maintain that single rows enable them to reduce the number of seeds planted per acre by as much as 40 percent [Petz--personal communication]. However, other growers who prefer to plant small vined varieties in double rows, believe that they use less seed since seeds planted in a single row tend to be planted close together. In contrast, by precision planting a double row, growers are able to precisely place the seed which reduces the total number of seeds planted [Robertson--personal communication].[63] In addition, when plants in a single row die due to adverse weather, diseases, insects or other problems, the remaining plants are unable to completely fill the open spaces. In contrast, plants in a double row are able

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[61] A standard tomato bed is 66 inches wide and contains two rows of tomato plants spaced approximately 20 inches apart. If growers plant on a 60 inch bed, they normally plant a single row using large vined varieties. If they plant on a 66 inch bed, they will typically plant a double row using small vined varieties [Fabbri--personal communication].

[62] One grower indicated that a hoeing crew only needs to remove weeds from a single row one time which reduces hoeing costs by 50 percent [Petz--personal communication]. However, a second grower believes that hoeing costs are higher with a single row since the plants are spaced closely together which makes it difficult to remove weeds [Robertson--personal communication].

[63] If a grower plants 50,000 seed per acre (43,560 square feet) there will be slightly more than one plant per square foot [Petz--personal communication].

to fill the open spaces [Petz--personal communication]. Thus, double rows are frequently planted early in the season when weather conditions are less predictable to increase the likelihood of producing an adequate stand [Kuehn--personal communication]. Some growers also prefer to use double rows since tomato plants tend to mature somewhat more evenly and about one week earlier than plants in a single row [Robertson--personal communication].

III.4.12. Importance of Fruit Shape:

Fruit shape is very important to canneries since whole peel consumers demand certain shapes, and since certain shapes are best suited for particular processed products. There are three primary fruit shapes: pear, round and blocky. Pear is almost always whole peeled and is primarily used in specialty packs. Round tomatoes are either used for paste, whole peel or dicing, while blocky tomatoes are used for paste [Kuehn--personal communication]. Although round tomatoes are better suited for whole peel than blocky varieties, they tend to have lower viscosity and less flexibility than blocky varieties. As a result, most canneries have switched to blocky varieties [Nichols--personal communication]. Blocky varieties are more flexible due to their greater firmness and higher recovery. They also tend to have superior viscosity, soluble solids and field holding. As a result, round type processing tomato varieties are almost non-existent today.[64] Some canneries such as Stanislaus Food,

[64] Processing plants that ask for round varieties are typically small and have not updated their equipment [Stewart and Storz--personal communication].

uses both blocky and pear shaped tomatoes since its customers have different taste and viscosity requirements [Gill--personal communication].

Technological advances also enable processors to peel blocky tomatoes just as efficiently as they are able to peel round tomatoes. For example, the canneries which initially used lye to remove the peel, now use steam which also can be used to remove the peel from blocky varieties. In addition, pinch peelers which at one time were more efficiently used with round tomatoes, have been modified to enable processors to efficiently remove the peels from blocky varieties [Stewart and Storz--personal communication].

III.4.13. Breeding for Acidity:

Organic acids are a critical determinant of the tart or sour flavor of processing tomatoes while they also influence the storability of processed tomatoes by inhibiting the spore germination of thermophilic organisms [Berry and Uddin, 1991].[65] Although eight organic acids are found in tomatoes, citric acid is the most predominant [Gould, 1992]. A fruit sample that has a pH above 4.5 and below .35 g citric acid/100 g of fresh weight, is commercially undesirable since it requires additional processing time and higher temperature to avoid spoilage [Berry and Uddin, 1991]. The lower the pH value (the higher the acidity) the less heat is needed for sterilization. The total acidity of tomatoes is determined by measuring the titraitable

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[65] High sugars and relatively high acids are required for best flavor. High acids and low sugars will produce a tart tomato, while high sugars and low acidity will produce a bland flavor [Grierson and Kader, 1986].

acidity [Gould, 1992].[66] Although research indicates that the inheritance of acidity is largely quantitative, evidence suggests that it is controlled by a single major gene. Thus, it has been possible to transfer high acidity from small fruited varieties to near commercial breeding lines [Stevens and Rick, 1986].

III.4.14. Importance of Jointless Pedicel:

Processors prefer to purchase tomatoes that are stemless to eliminate the need to remove the stem while the fruit is being processed. It is much more advantageous to use stemless varieties for whole peel and dice production than for paste production since the stems are easily removed while the paste is being cooked [Gill--personal communication]. However, very few hybrids have jointless pedicels since it is a recessive trait [Kuehn--personal communication]. Fortunately, most varieties "shake well" and separate easily from the stem including Brigade and BOS 3155 [Mullen--personal communication]. Several years ago, growers planted a variety that had good processing characteristics and high yields but was rejected by processors since it was considered too "stemy" [Brown--personal communication].

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[66] The total acidity and the pH level are not always closely correlated since the pH is oftentimes buffered by other constituents of the tomato [Tigchelaar, 1986]. The pH can vary due to the variety and variety maturity, seasonal variations in growing conditions, growing area, handling, field holding, salt and processing variations [Gould, 1992].

CHAPTER IV

VARIETY SELECTION

The purpose of chapter IV is to provide a detailed description of the factors that influence the selection of varieties by growers and processors. The first part of the chapter provides background data on varieties used between 1990 and 1995. The second section describes the choice growers and processors have to make between using either open pollinated (OP) or hybrid varieties. The third section focuses on factors which influence processor variety selections. The final section describes the role that growers play in selecting varieties. Much of the information contained in the chapter is based on a mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.[1]

IV.1. Variety Background Information:

IV.1.1. Relationship Between Characteristics and Variety Performance:

To the untrained eye, there appears to be very little phenotypic variation among processing tomato varieties. However, tests have revealed that significant differences exist within twenty to thirty important characteristics which can have a sizable impact on the yield and quality of the harvested fruit. This includes important differences in soluble solids (sugar content), yield potential, fruit shape, viscosity, canopy type, vine size, color, field holding, heat and drought tolerance, and nematode

[1] Twenty percent of the 402 growers surveyed responded to the survey. A copy of the survey is included in Appendix A.

and disease resistance. The differences have led to the development of hundreds of different hybrid tomato varieties and several dozen OP varieties that combine the characteristics in different ways. During a typical year, growers statewide plant approximately 200 of the varieties. However, twenty-five major varieties comprise over 80 percent of the inspected loads. The remaining loads are contributed by minor use varieties which each comprise less than 1 percent of the market.

The major varieties dominate the market because they have a somewhat superior set of characteristics which are demanded by the majority of growers and processors. Minor use varieties are purchased for a number of reasons. First, some processors have a very specific need. For example, some processors may like a variety because it peels especially well, has good color, or because it has very high soluble solids [Mullen--personal communication]. Second, certain varieties are needed because they grow well in areas with unique soils, weather conditions and/or cultural practices. Third, varieties with different maturity dates are needed to provide growers with the flexibility to space out their harvest to satisfy the needs of their processors [Herringer--personal communication].[2] Fourth, some processors are not fully aware of all the genetic characteristics of each of the varieties they include on their variety lists, so they tend to use more varieties than they need [Storz--personal communication]. Fifth, processors like to use a mix of varieties just in case one of the varieties they select performs poorly [Mast--personal communication].

The importance of each of the top twenty-five varieties varies from one county

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[2] During 1995, some growers planted more varieties than normal since wet weather forced them to replant using early maturing varieties [Turkovich--personal communication].

to the next. For example, BOS 3155 had a load share of nearly 31 percent in Yolo county. In comparison, its load share was only 16.8 percent in San Joaquin county and 19.5 percent in Fresno county (Table 4.1). This may indicate that Yolo county's climate, soil, diseases and other factors are better suited to grow BOS 3155 than are the same factors in San Joaquin and Fresno counties. The same scenario may apply equally well to Heinz 8892, which had a much larger load share in San Joaquin county than in either Yolo or Fresno counties. However, it is also possible that San Joaquin county has a high percentage of growers who contract with Heinz which requires its growers to plant a high proportion of Heinz varieties.[3]

IV.1.2. Top Twenty-Five Varieties Harvested During 1995:

The performance of varieties in certain characteristic categories, such as mold and soluble solids, affects grower and processor selections of varieties in future years (Table 4.2). The top variety during 1995 was BOS 3155 which comprised 23 percent of the delivered loads. The next most widely used varieties were Heinz 8892 (17.5 percent), Brigade (6.15 percent), Heinz 3044 (5.4 percent) and Heinz 9280 (3.74 percent). The top five varieties represented nearly 56 percent of the inspected loads. In addition, each of these varieties has been included among the top ten for several years. The varieties that fell below the top fifteen load shares each comprised less than 1 percent of total production. The load shares of the top five varieties may have been substantially larger than the load shares for the remaining varieties since

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[3] The Heinz variety groups are listed in the California Tomato Growers Association, Inc. 1995 Negotiated Prices.

Table 4.1. Load Shares of the Top Twenty-Five Varieties by Volume Delivered to California Processors During 1995 For Yolo, San Joaquin and Fresno Counties

Variety	Share of Delivered Loads			
	State	Yolo	San Joaquin	Fresno
	----------Percent----------			
BOS 3155 (HYBRID)	22.99	30.97	16.80	19.52
HEINZ 8892	17.46	14.72	29.51	14.86
ASG XPH 5210 BRIGADE	6.15	8.87	4.51	3.96
HEINZ 3044	5.40	4.91	1.88	7.85
HEINZ 9280	3.74	4.11	2.34	3.04
PETO NEMA 512	2.87	2.13	3.65	2.81
RNK NVH 4762 LA ROSSA	2.48	.82	2.23	5.58
U 370, VAN DEN BERGH	1.74	3.36	.39	1.00
ASG APT 127 (XPH 12047)	1.55	3.08	.44	.83
CAMPBELL CXD 152	1.52	1.71	2.70	.50
CAMPBELL CXD 109 SHASTA	1.47	3.32	0.00	.15
FM 9208E, PEELMECH	1.37	.23	1.66	2.82
FMX 1047NP	1.15	.59	1.04	1.59
PETO 111B	1.08	.30	.79	1.29
FM APEX 1000	1.01	.23	0.00	1.78
HEINZ 9281	.96	1.02	.09	.75
SUN 5715	.95	0.00	1.37	2.30
PETO NEMA 1435 (PSX 3594)	.88	.81	1.32	1.09
SUN 6200	.83	1.27	.35	.70
FM E6203	.82	.14	.02	1.86
PETO NEMA 1200	.82	.28	.37	1.76
SUN 1642	.77	0.00	3.84	1.30
RNK NVH4781 (0-545)	.73	.60	.46	.90
H 282	.72	.25	2.47	.45
BOS 707 (HYBRID)	.71	.24	.97	1.72
Total[a]	80.17	83.96	79.20	80.41

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1995.

[a] The total figures only reflect the load share contributions of the top twenty-five varieties delivered to inspection stations during 1995.

Table 4.2. Average County and State Levels of Selected Quality Parameters of Loads Delivered to California Processors During 1995

County and Region	Levels of Key Quality Parameters[a]			
	Mold	Limited Use	Soluble Solids	Comminuted Color Reading
	----------Percent----------			
Region I:				
Yolo	1.4	1.5	5.14	24.3
San Joaquin	1.1	1.9	5.18	23.1
Sacramento	1.8	1.6	5.04	24.0
Solano	1.3	2.0	5.14	24.3
Stanislaus	1.2	2.0	5.23	22.4
Colusa	2.1	1.6	5.11	25.4
Sutter	2.2	1.3	5.31	24.3
Butte	5.0	1.4	5.43	23.0
Glenn	3.2	0.9	5.18	24.1
Region II:				
Merced	1.6	2.1	5.31	23.0
Fresno	0.9	2.8	5.28	23.7
Kern	1.2	2.0	5.01	23.5
Kings	1.5	3.8	5.56	23.2
Madera	1.3	3.3	5.29	24.4
Tulare	3.5	2.4	4.76	23.9
Region III:				
Contra Costa	0.5	3.2	5.13	25.1
Monterey	0.4	2.6	5.04	24.0
San Benito	1.0	1.6	5.42	22.5
Santa Clara	0.9	2.8	4.98	23.9
Region IV:				
Santa Barbara	1.2	2.4	5.01	25.5
Ventura	1.3	2.4	5.15	22.7
Region V:				
Imperial	2.0	3.0	4.50	25.0
State Total	1.3	2.1	5.21	23.9

Source: Processing Tomato Advisory Board (PTAB): Average Defects by Variety (for each county and state) For 1995.

[a] Loads with a mold level above 5 percent or an agtron color reading usually above 30 (established by the Director of Food and Agriculture) are rejected.

they performed well when graded for one of several quality characteristics. These characteristics include: limited-use, soluble solids, mold and color.

Limited-use may be the most important characteristic since four of the top five varieties had some of the lowest percentages of limited-use among the top twenty-five varieties. The one exception is Brigade which ranked tenth for limited-use (Table 4.3A).[4] Since limited-use is very important to both growers and processors, it is not surprising that most of the top varieties performed well in this category. The state average for limited-use during 1995 was 2.1 percent. Loads inspected in Region I had the lowest percentages of limited-use, while loads inspected in the other regions experienced somewhat higher percentages. This may have occurred since the majority of processing plants are located in Region I, which reduces the damage associated with transporting tomatoes over long distances. Thus, growers who are located far from processing plants, attempt to select varieties with long field holding to reduce the damage they suffer during transport.

The state average for soluble solids during 1995 was 5.21 percent. The highest soluble solids were recorded by growers in Kings county who achieved average soluble solids of 5.56 percent. In general, however, there was very little variation in the percentage of soluble solids among the state's counties. Since growers in Tulare, Imperial and Santa Clara counties achieved soluble solids that were less than 5 percent, they may have suffered quality deductions. The soluble

[4] It is somewhat surprising that the average limited use of the top twenty-five varieties (2.6%) is substantially higher than the state average for all varieties (2.1%).

Table 4.3A. Percent and Rank of Limited-Use and Soluble Solids for the Twenty-Five Varieties with the Largest Load Shares Inspected by PTAB During 1995

Variety	Share of Loads[a] (Percent)	Limited-Use		Soluble Solids	
		Percent	Rank	Percent	Rank
BOS 3155 (HYBRID)	22.99	1.4	2	5.42	4
HEINZ 8892	17.46	1.8	5	5.17	11
ASG XPH 5210 BRIGADE	6.15	2.5	10	5.19	9
HEINZ 3044	5.40	1.5	3	4.90	22
HEINZ 9280	3.74	1.2	1	4.91	21
PETO NEMA 512	2.87	2.2	9	5.02	18
RNK NVH 4762 LA ROSSA	2.48	2.7	11	5.12	13
U 370, VAN DEN BERGH	1.74	2.1	8	5.05	17
ASG APT 127 (XPH 12047)	1.55	1.9	6	5.11	14
CAMPBELL CXD 152	1.52	3.5	16	5.42	4
CAMPBELL CXD 109 SHASTA	1.47	3.0	13	5.45	3
FM 9208E, PEELMECH	1.37	3.3	14	5.08	16
FMX 1047NP	1.15	1.7	4	5.18	10
PETO 111B	1.08	3.7	18	5.50	2
FM APEX 1000	1.01	1.9	6	5.30	6
HEINZ 9281	0.96	1.9	6	5.09	15
SUN 5715	0.95	3.6	17	4.93	20
PETO NEMA 1435 (PSX 3594)	0.88	4.0	19	5.55	1
SUN 6200	0.83	2.7	11	5.00	19
FM E6203	0.82	3.4	15	5.26	7
PETO NEMA 1200	0.82	2.7	11	5.38	5
SUN 1642	0.77	2.9	12	4.83	23
RNK NVH4781 (0-545)	0.73	3.5	16	5.24	8
H 282	0.72	2.7	11	5.11	14
BOS 707 (HYBRID)	0.71	3.6	17	5.15	12
Average		2.6		5.17	
Standard Deviation		.8		.20	

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1995.

[a] During 1995 423,507 loads were delivered to processors. The top 25 varieties contributed 341,210 loads--80.6 percent of the total.

solids in Imperial county are usually low since growers plant early maturing varieties which tend to have inferior processing qualities. However, they make-up for the deductions with higher than average yields. Ideally, growers would prefer varieties with somewhat higher soluble solids to capture higher incentive payments, while maintaining or increasing yields. Although processors claim that high soluble solids reduce their costs and improve product quality, only one of the varieties included among the top five load shares was ranked among the top five for soluble solids (BOS 3155). The other four were ranked far down the list. Two of the top Heinz varieties had soluble solids below 5 percent. However, since Heinz needs high viscosity for catsup production, and since it can legally add sugar to catsup, it is willing to accept low solids. Growers who grow Heinz varieties are willing to suffer deductions for low solids since the company's varieties tend to produce very high yields.

Loads inspected during 1995 contained an average of 1.3 percent mold. Growers who reside in Contra Costa and Monterey counties (Region III), had the lowest mold percentages (.5 and .4 percent respectively), while Butte county (Region I), had the highest (5 percent). Fresno and San Joaquin counties were slightly under the state average, while Yolo county was slightly above the average. In general, the mold levels were highest in Region I which is indicative of somewhat higher than average rainfall and dew formation. To remain competitive, growers in counties with high mold counts frequently replace older varieties with new varieties that have improved mold resistance. However, it is uncertain how important the mold level is to variety selection since three of the varieties with the largest load shares, were ranked below the top five for this characteristic (Table 4.3B).

Table 4.3B. Percent and Rank of Mold and Color for the Twenty-Five Varieties with the Largest Load Shares Inspected by PTAB During 1995

Variety	Share of Loads[a] (Percent)	Mold Level		Color Reading	
		Percent	Rank	Level	Rank
BOS 3155 (HYBRID)	22.99	1.6	11	23.6	6
HEINZ 8892	17.46	1.5	10	22.8	1
ASG XPH 5210 BRIGADE	6.15	1.1	7	24.3	12
HEINZ 3044	5.40	0.8	4	23.1	2
HEINZ 9280	3.74	0.6	2	24.8	14
PETO NEMA 512	2.87	1.8	13	23.7	7
RNK NVH 4762 LA ROSSA	2.48	0.8	4	23.8	8
U 370, VAN DEN BERGH	1.74	1.7	12	23.4	4
ASG APT 127 (XPH 12047)	1.55	1.1	7	25.4	17
CAMPBELL CXD 152	1.52	1.3	8	26.0	18
CAMPBELL CXD 109 SHASTA	1.47	0.7	3	28.5	19
FM 9208E, PEELMECH	1.37	0.9	5	24.2	11
FMX 1047NP	1.15	0.5	1	25.5	18
PETO 111B	1.08	2.4	16	23.5	5
FM APEX 1000	1.01	1.4	9	25.1	15
HEINZ 9281	0.96	1.2	8	24.7	13
SUN 5715	0.95	0.9	5	23.7	7
PETO NEMA 1435 (PSX 3594)	0.88	1.5	10	24.2	11
SUN 6200	0.83	2.2	15	23.6	6
FM E6203	0.82	1.0	6	24.2	11
PETO NEMA 1200	0.82	0.5	1	25.3	16
SUN 1642	0.77	0.9	5	24.1	10
RNK NVH4781 (0-545)	0.73	1.0	6	23.2	3
H 282	0.72	1.9	14	23.9	9
BOS 707 (HYBRID)	0.71	0.9	5	23.8	8
Average		1.2		24.3	
Standard Deviation		0.5		1.2	

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summary for 1995.

[a] During 1995 423,507 loads were delivered to processors. The top 25 varieties contributed 341,210 loads--80.6 percent of the total.

The state average comminuted color reading was 23.9 during 1995. Although color is considered to be a very important varietal characteristic, there was very little variation in the comminuted color readings among varieties inspected during 1995. In addition, most of the comminuted color readings were very similar among the top twenty-five varieties. However, three of the varieties with the largest load shares were ranked below the top five varieties with the best color. Thus, color may not play a decisive role in the selection of varieties by growers.

IV.2. Open Pollinated vs. Hybrid Varieties:

IV.2.1. History of OP and Hybrid Variety Use:

During the first few decades of the California processing tomato industry, the seed market consisted of only a few open pollinated (OP) varieties. The standard OP VF-145B (also known as 78-79) dominated the market during the 1960s. Although it had good solids, it also had several major drawbacks, including a tendency to develop soft root and suffer high limited-use. During the 1970s, there were approximately 15 OP varieties to choose from, and for a very brief period UC 82 replaced VF-145B as the dominant OP variety [Rufer--personal communication]. It represented a major step forward in varietal development since it has a determinate compact vine and high fruit set. However, due to low solids, it is best suited for catsup production [Mullen--personal communication].[5]

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[5] Although UC 82 was dominant in California for only a very short time, it is still the leading variety used worldwide [Stewart and Storz--personal communication].

Shortly thereafter, an OP variety developed by Ferry Morse called 6203 (similar to Peelmech 9208) became the dominant variety and stayed dominant for the next dozen years.[6] Until 1993, it was still among the ten most widely used varieties [Stewart and Storz--personal communication]. Meanwhile, plant breeders were developing hybrid varieties with sufficiently improved growing and processing characteristics to justify their significantly higher development cost and retail price. In 1976, the first hybrid processing tomato varieties were introduced in California. Within a few years, hybrids began to dominate the market despite their much higher retail price.[7] Between 1985 and 1990, the market share of hybrid varieties expanded from 26 to 52 percent. By 1995, the market share of hybrid varieties had expanded to 93 percent [Boleda, 1992, Brown--personal communication].[8]

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[6] Peelmech 9208 is used interchangeably with 6203 by PTAB. Shortly after Ferry Morse released 6203, other companies released identical versions of the same variety since Ferry Morse never obtained variety protection (PVP) for 6203. As a result, Ferry Morse made a selection out of 6203 which they called 9208 (Peelmech) for which they obtained PVP. Although they are genetically different, they share many of the same traits. It is now harder for seed companies to copy each others varieties due to the development of very sophisticated technology such as electrophoresis which can be used to identify genetic patterns in each variety. Thus, new varieties must be significantly different to be marketable [Stewart and Storz--personal communication].

[7] Hybrid seed sells for between $150-$300 per one-hundred thousand seeds, while OP seed sells for $25-$40 per pound. The primary reason most hybrid seed is sold in one-hundred thousand seed units is because the weight of each unit ranges between one-half and one pound depending on the seed size. This is important since the cost of producing each pound of hybrid seed is much greater than the cost of producing an identical amount of OP seed.

[8] Approximately twenty OP varieties were inspected by PTAB during 1995--which is approximately 13 percent of all the inspected varieties. The only important OP variety still being sold is Petoseed 111B, which has very good viscosity and fairly good solids [Kennedy--personal communication].

IV.2.2. Impact of Hybrids on Seed Companies and Dealers:

Few seed companies are actively involved in the development of OPs since processors and most growers prefer hybrids. In addition, seed companies earn a higher rate of return from selling hybrid seed [Cooley--personal communication]. They also are able to protect their proprietary research on hybrids, unlike OPs, which can easily be reproduced by competitors.[9] Seed companies also prefer hybrids because they can exploit heterosis for quantitative traits such as improved earliness and yield, and quality attributes such as soluble solids, viscosity and color [Gould, 1992].

Although the profit margin from selling hybrids is smaller than the profit margin from selling OPs, seed suppliers and dealers earn more profits from each unit sold. For example, if dealers increase the price of an OP by 10 percent from $20 to $22 per hundred-thousand seeds, their profits increase by $2. On the other hand, if dealers increase hybrid seed prices by 10 percent from $200 to $220 per hundred-thousand seed unit, their profits increase by $20. However, dealers must be careful when setting hybrid seed prices since the demand for hybrid varieties tend to be more elastic than the demand for OP varieties due to the high price. Thus, a slight price miscalculation by seed dealers can wipe out their profits [Stewart and Storz--personal communication].

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[9] Many growers believe that if breeders spent as much time and money developing OPs as hybrids, they could produce OP's of equal quality [Remonda--personal communication]. They also believe that if genetic markers were incorporated into OP varieties, seed companies would be able to protect their variety patents and earn profits comparable to what they earn by selling hybrids [Yerxa--personal communication]. Although growers would pay more for the protected OP seed, it would still cost significantly less than hybrid seed since hand pollination would be eliminated.

Another advantage of hybrids is that, in some cases, seed companies can spend less time developing a new hybrid variety than a new OP variety which contains the same set of desirable characteristics. Time is crucial to varietal development since the first company that markets a desirable variety usually captures the market. Thus, breeders do not have the luxury of testing and developing a variety for five to ten years [Nichols--personal communication]. For example, by the time Harris Moran marketed Orion, which is an OP with nematode resistance, new hybrid varieties were being sold that contained both nematode resistance and improved fruit firmness [Stewart and Storz--personal communication].

A potential disadvantage of hybrid varieties is that the seed must be produced overseas to reduce the labor costs associated with hand pollination. The production of seed overseas affects both the timing of seed deliveries and seed production decisions. Most hybrid seed is harvested and cleaned only several weeks before it is sold in the United States [Timothy--personal communication]. Thus, the seed will not be available when needed if there are delivery, management or political problems [Nichols--personal communication].[10] If seed companies are unable to supply a particular variety they may lose market share.

IV.2.3. Why Most Growers and Processors Prefer Hybrid Varieties:

Processors prefer hybrid varieties because of their superior color, soluble solids, viscosity and other traits [Pruett--personal communication]. For example, no

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[10] Plant breeders are trying to develop male sterile varieties which would preclude the need to produce seed overseas [Brown--personal communication].

commercial OP varieties have the 35 percent peel and dice recovery of BOS 3155, the viscosity of Heinz 8892, or the agronomic resilience of Brigade [Stewart and Storz--personal communication].

Most growers prefer hybrids because they tend to have improved disease resistance, earliness, consistent field production--particularly under less than optimal growing conditions, adaptability to a wide range of environmental conditions, and higher yields [Tigchelaar, 1986, Boleda, 1992].[11] In a 1990 study, hybrids yielded between 35 and 40 tons per acre while the top OPs yielded between 32 and 33 tons per acre [Boleda, 1992]. Hybrids also are generally much hardier than OPs, which makes it possible to plant them back to back on the same piece of land [Timothy--personal communication]. This is particularly important in the northern part of the state where the soils have more disease and nematode problems than in the southern part of the state due to more intensive farming and poor crop rotations [Angell--personal communication]. As a result, until recently, the rate of adoption of hybrid varieties has been higher in the north than in the south.

Hybrids also permit much greater harvesting flexibility due to a much broader range of maturity dates than OPs. Growers can plant two hybrid varieties on the same day and harvest the first in 108 days and the second in 130 days. This enables them to stretch out the harvest by two to three weeks [Brown--personal communication]. It also reduces the probability that the tomatoes will rot in the field if processors are running at capacity.

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[11] OPs tend to deteriorate much faster than hybrids when they are exposed to high temperatures and drought [May--personal communication].

Many growers have stopped planting OPs either due to poor performance or due to a lack of suitable varieties. One grower planted a Harris Moran OP variety called Niagra NCX 3032 which produced very high yields but was susceptible to nematodes. On one occasion, the variety yielded sixty tons per acre. On another occasion, when the fumigation used to control nematodes was done incorrectly, the yield fell to only fifteen tons per acre [Fabbri--personal communication].[12] A second grower indicated that he stopped using the Ferry Morse OP variety FM 9208 because his incentive payments had fallen to unacceptable levels due to poor quality [Petz--personal communication]. A third grower stated that since there are few if any early maturing OP varieties, growers are oftentimes forced to rely on hybrids [Turkovich--personal communication].

IV.2.4. Why Some Growers and Processors Prefer OP Varieties:

Some growers still prefer OP seed because it costs eight to ten times less than hybrid seed. Some members of the processing tomato industry are not certain hybrids are worth the additional cost since hybrid yields are not always predictable. As a result, most processors include at least one OP on their approved variety list to

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[12] Harris Moran marketed an OP variety called Orion which is nematode resistant. Although the price was much lower than hybrid varieties with nematode resistance, Harris Moran was only able to sell 3000 pounds of the variety. This occurred since it failed to mask some of the undesirable characteristics that were genetically linked to the nematode resistance [Stewart and Storz, Jacobs, Stevens--personal communications].

placate growers who complain about the high cost of hybrid seed [Woolf--personal communication].[13]

Under the right circumstances, OPs perform as well as hybrids--such as in the Fresno area where there are fewer disease and stress problems [May, Hirahara--personal communication]. Open pollinated varieties also are sometimes preferred by growers since they reduce the risk of developing a poor stand early in the season and since growers usually plant far fewer hybrid seeds per acre than open pollinated seed due to their cost.[14] In addition, OPs reduce the financial loss associated with a hybrid variety that must be replanted due to poor germination [Brown--personal communication]. To compensate for the reduced hybrid seeding rate, growers use expensive and not always reliable precision planters and additional pesticides to reduce disease and insect damage [Miyao--personal communication]. However, some growers plant an equal amount of hybrid seed and OP seed per acre since they believe the money saved on seed is not worth the increased risk of producing a poor stand [Cooley--personal communication].

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[13] Hybrid seed is much more expensive than OP seed since the plants must be hand-pollinated. Since the cost of the labor needed to hand pollinate each plant would be prohibitive in the U.S., the seed is produced in developing countries such as Taiwan, China, India, and Thailand where labor costs are much lower. Seed companies also charge a much higher price since hybrids tend to have a much shorter market life span than older varieties. Thus, to recoup the money spent on research and development, they charge a premium [Boleda, 1992].

[14] Growers generally plant between 1 and 1.5 pounds of OP seed per acre to make certain they get an adequate stand. On average, there are approximately 160 thousand seeds per pound. Since hybrid seed is much more expensive, growers tend to use 60,000 hybrid seeds or fewer per acre depending on when the seed is planted [Timothy--personal communication]. For the late season harvest, growers frequently plant fewer seeds since emergence is more uniform [Fabbri--personal communication]. With precision planters, it is sometimes possible to plant 50,000 or fewer hybrid seeds per acre [Woolf--personal communication].

Some of the old OP varieties, such as 6203 and APEX 1000 which were introduced by Ferry Morse fifteen to twenty years ago, continue to be used in areas that have suitable growing conditions and good soils [Storz--personal communication]. They are both highly adaptable, have medium viscosity and solids, high yield and can be used for almost any type of cannery product. APEX 1000 is still the standard variety used for whole peel tomatoes although it is losing ground to BOS 3155 [Nichols--personal communication]. One grower plants APEX 1000 because it has very good field holding, high yield and very few disease problems. The processor he sells to likes the variety since it is an excellent whole peel variety [Vosti--personal communication].[15] Another grower has had more success growing FM 6203 than hybrids since it has been more consistent and reliable over the years.[16] However, he is gradually planting less acreage with FM 6203 because it is no longer on processors' preferred lists [Merwin--personal communication].

IV.3. Number of Varieties Planted by Each Grower:

Between 1990 and 1995, the number of varieties submitted for inspection to state grading stations fluctuated between a high of 220 during 1994 and a low of 156 during 1990 (Table 4.4). Fresno county consistently submitted the most varieties

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[15] Most processors prefer that growers not use OPs since they have fewer desirable characteristics. For example, although growers love UC82, most canneries will not accept it because they can get higher case yield from other varieties [Fawcett--personal communication].

[16] The grower uses the same cultural practices for his OPs and hybrids but for some reason the OPs respond better [Merwin--personal communication].

Table 4.4. Number of Varieties Planted Per County, Region and State for Selected Years

County and Region	Number of Varieties Planted For Selected Years					
	1990	1991	1992	1993	1994	1995
Region I:						
Yolo	101	112	96	113	121	124
San Joaquin	62	74	61	71	87	97
Sacramento	50	51	44	55	48	38
Solano	66	73	59	66	87	80
Stanislaus	65	65	59	51	53	62
Colusa	51	62	59	67	78	84
Sutter	48	63	57	62	71	70
Butte	-----	-----	-----	-----	-----	4
Glenn	-----	-----	-----	-----	-----	7
Region II:						
Merced	48	54	48	52	51	47
Fresno	110	143	129	120	157	146
Kern	34	14	16	16	27	24
Kings	22	37	21	37	43	32
Madera	-----	-----	-----	-----	-----	8
Tulare	-----	-----	-----	-----	-----	6
Region III:						
Contra Costa	33	23	29	29	15	32
Monterey	7	9	7	5	6	4
San Benito	13	12	6	14	17	13
Santa Clara	10	13	8	7	8	8
Region IV:						
Santa Barbara	3	2	2	6	5	6
Ventura	17	10	10	13	12	11
Region V:						
Imperial	23	19	8	12	14	14
Riverside	5	2	-----	-----	-----	-----
State Total	156	206	180	185	220	208

Source: Processing Tomato Advisory Board (PTAB): Average Defects by Variety (for each county and state), annual summaries between 1990-95.

followed by Yolo and San Joaquin counties. The three counties also were the largest producers of processing tomatoes in California.

During a typical year, growers plant anywhere from one to twenty-five different varieties. The number of varieties they plant depends on the number of acres planted, soil conditions, processor requirements and the number of experimental, early season, late season and niche varieties desired. A variety that performs well on one part of the farm may do poorly on another part. Most growers tend to plant four to five main varieties on the majority of their acreage which usually consist of the most popular varieties such as BOS 3155, Brigade and Heinz 8892. The rest of their acreage is planted with minor, niche and experimental varieties which are only grown on a few acres.

During 1995, the average grower planted approximately seven processing tomato varieties. The most varieties planted by any of the survey respondents was seventeen while one was the lowest number (Table 4.5). Growers with small farms planted approximately four varieties while growers with large farms planted an average of eleven varieties. However, some of the growers with small farms planted almost as many, and in some cases more, varieties than growers with large farms (Table 4.6). Growers indicated that the two most important reasons why they plant more than one variety are the harvest schedule and processor requirements. Other factors such as seed availability, disease and nematode potential, soil and rainfall variability, and the use of the variety in intermediate and end-use products were judged to be much less important (Table 4.7).

Table 4.5. Grower Estimates of the Number of Processing Tomato Varieties Growers Planted per Farm During 1995, by Region

Growing Region	Number of Varieties Planted per Farm			
	Average	Lowest Number	Highest Number	Standard Deviation
Region I	7.00	1	17	4.9
Region II	7.14	1	14	3.6
Region III	3.67	1	6	1.9
State	6.75	1	17	4.3

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

Table 4.6. Grower Estimates of the Number of Processing Tomato Varieties Growers Planted per Farm During 1995, by Farm Size

Farm Size[a]	Number of Varieties Planted per Farm			
	Average	Lowest Number	Highest Number	Standard Deviation
Small Farms	3.90	1	14	2.45
Medium Farms	7.12	3	13	3.30
Large Farms	11.00	2	17	4.45
State	6.75	1	17	3.21

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Small farms are defined as having 500 or fewer acres. Medium sized farms are defined as having between 501-1000 acres while large farms are defined as having 1000 or more acres.

Table 4.7. Grower Ranking of Factors That Help to Explain Why They Plant More Than One Variety, by Region

Factors	Importance of Factors by Growing Region			
	Region I	Region II	Regions III-V	State
	----------Grower Ranking of Factors[a]----------			
Seed Availability	2.79	2.55	2.00	2.66
Harvest Schedule	4.45	4.38	2.80	4.31
Early Season Harvest	3.53	4.05	3.80	3.71
Late Season Harvest	3.90	3.42	2.00	3.62
Processor Requirements	4.33	4.36	3.80	4.30
End Use Product	3.05	3.22	2.80	3.08
Disease Potential	3.71	3.26	3.40	3.55
Nematode Potential	3.65	3.40	4.20	3.62
Soil Variability	3.39	2.79	3.00	3.18
Rainfall Variability	2.76	1.71	2.40	2.43
Experimental Trials	2.43	1.72	1.40	2.13

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Growers ranked the importance of each trait from 1 to 5. A ranking of 5 indicates that the factor is very important while a ranking of 1 indicates that the factor is unimportant.

IV.3.1. Changes in the Use of Varieties Over Time:

Most varieties usually remain popular for only a few years before new and improved varieties take their place. In order to remain competitive and possibly earn short-term profits above the long-run equilibrium, growers and processors constantly seek out new and improved varieties that will give them a slight edge over the competition. A one-ton yield increase per acre can mean the difference between a grower losing money and earning a profit. Growers also want to reduce their deductions while increasing their incentive payments. Brigade was replaced by BOS 3155 as the number one variety largely because BOS 3155 has superior field holding and somewhat better soluble solids [Angell--personal communication].

Varieties also lose their appeal because more virulent forms of diseases that affect tomato plants gradually become dominant and are able to circumvent the plant's defense mechanisms. For example, some of the older varieties are being replaced by new varieties resistant to Bacterial speck, a bacterial disease that only recently became a significant problem [Kuehn--personal communication].

The varieties inspected by PTAB during 1995 had been in use for an average of 3.2 years (Table 4.8). However, Region III growers had used their varieties for an average of 5.4 years since they relied more heavily on older OP varieties than growers in other regions. The longest any variety had been used by any of the survey respondents was fifteen years. Many of the varieties had only been used for one year. The rapid variety turn-over stands in stark contrast to the length of time many varieties were listed in seed catalogs published between 1868 and 1936. Many varieties were listed for twenty years or longer, and a variety called Cherry Red

Table 4.8. Grower Estimates of the Average Number of Years Processing Tomato Varieties Harvested During 1995 Have Been Grown by California Growers, by Region

Growing Region	Length of Use of Varieties			
	Average	Lowest Number	Highest Number	Standard Deviation
	----------Years----------			
Region I	3.00	1.00	11.00	2.55
Region II	3.20	1.00	11.00	2.50
Region III	5.36	1.00	15.00	4.00
State	3.16	1.00	15.00	2.70

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

was listed in the seed catalogs every single year (see Table 3.1). This seems to indicate that growers and processors have become more sensitive to small varietal differences.

Only 44.6 percent of the varieties inspected statewide by PTAB during 1991 were also inspected by PTAB during 1995 (Table 4.9). Of the twenty-five varieties with the largest statewide load shares during 1991, only five either maintained or increased their load shares the following year, while only BOS 3155 experienced a load share increase each of the five years. The load shares of the four OP varieties which were included among the top ten varieties during 1991, fell considerably by 1995, and only FM E 9208 had a load share larger than 1 percent. Meanwhile, the load share of the number one variety (Brigade), fell from 10.87 percent in 1991 to only 6.15 percent in 1995 (Table 4.10).

In Yolo county, only one of the varieties included among the top ten load shares during 1991 was an OP (Diego, HM 3075). By 1995, Diego's load share fell from 6.68 percent to zero. Brigade's share, which was the largest in Yolo county during 1991, increased during 1992 and 1993 before dropping off the following year. The only variety that increased its load share over the five year period was BOS 3155 (Table 4.11). In contrast, four of the varieties included among the top ten load shares in San Joaquin during 1991 were OP varieties. This included the top variety--Peelmech E9208 (FM), which held a 14.26 percent load share. However, by 1995, only one of the OPs inspected in San Joaquin county still comprised a significant load share (SUN 1642). BOS 3155 was the only variety which experienced an increased

Table 4.9. Statewide Percentage Changes in the Use of Base Year Varieties Inspected by PTAB Between 1991 and 1995

	Use of Base Year Varieties Over Time[a]				
Base Year	1991	1992	1993	1994	1995
	----------Percent----------				
1991	100.0	58.7	53.9	52.4	44.6
1992		100.0	72.8	63.9	58.3
1993			100.0	72.6	70.8
1994				100.0	76.8

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summaries for 1991-1995.

[a] For example 58.7 percent of the varieties used during 1991 were used again during 1992.

Table 4.10. Statewide Load Share Changes Between 1991 and 1995 for the Twenty-Five Varieties with the Largest Load Shares During 1991

Top 25 Varieties Harvested During 1991	Share of Delivered Loads				
	1991	1992	1993	1994	1995
	Percent				
ASG XPH 5210 BRIGADE	10.87	**12.68**[a]	12.14	11.18	6.15
FM E 6203	7.70	3.99	3.83	1.84	.82
PETO NEMA 512	5.43	5.36	5.27	5.23	2.87
FMX 785 (E0204)	5.22	2.94	1.46	1.02	.28
FM APEX 1000	4.73	4.41	3.68	2.95	1.01
FM E 92081, PEELMECH	4.72	**4.92**	3.05	2.61	1.37
DIEGO, HM 3075	4.36	3.59	1.55	.14	.01
CAMPBELL CXD 100, ALTA	3.81	2.27	.59	**.89**	.37
PETO NEMA 1401	3.17	2.78	2.38	.69	.29
PETO NEMA 1200	3.13	1.88	**2.00**	.89	.82
BOS 3155 (HYBRID)	3.12	**9.75**	**15.92**	**20.86**	**22.99**
KS 5715 (AV, AG, SUNSEED)	3.12	2.98	2.52	1.66	.95
HEINZ 2710	2.98	2.6	1.60	1.44	.65
RNK NVH 4762, LA ROSSA	2.71	**3.91**	2.92	2.77	2.48
SPECTRUM 579 (PSX 57994)	1.97	1.67	1.25	.81	.10
SUN 1642	1.89	1.48	**1.79**	1.05	.77
PETO 111B	1.55	**2.07**	**2.55**	1.84	1.08
RNK 12 GS	1.53	1.28	.98	.30	.27
PETO NEMA 1400	1.41	1.83	.68	.41	.35
UC 82 (ALL TYPES)	1.34	.65	**.73**	.38	.20
PETO SAUSALITO, PSX 7098	1.31	1.07	.27	.01	.00
HEINZ 8773	1.09	**1.17**	1.00	.77	.51
FM 48432, YUBA	1.05	.63	.43	.05	**.12**
CAMPBELL CXD 109, SHASTA	.95	.29	.21	**.70**	**1.47**
CAMPBELL CXD 101, LASSEN	.87	.36	.03	.00	.00
Total	80.13	75.56	68.83	60.49	45.93

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summaries for 1991-1995.

[a] The percentages in bold type indicate that the percentage share of the variety increased from the previous year.

Table 4.11. Yolo County Load Share Changes Between 1991 and 1995 for the Twenty-Five Varieties with the Largest Load Shares During 1991

Top 25 Varieties Harvested During 1991	Share of Delivered Loads				
	1991	1992	1993	1994	1995
	Percent				
BRIGADE, H 5210	13.66	**20.11**[a]	**21.00**	17.67	8.87
FMX 785 (E 0204)	11.82	6.09	3.31	2.20	0.49
DIEGO, HM 3075	6.68	3.56	2.10	0.19	-----
NEMA 512	6.27	6.41	5.60	5.30	2.13
ALTA, CXD 100	6.17	2.31	0.63	1.39	0.20
NEMA 1401	5.61	4.40	2.87	1.24	0.47
BOS 3155 (HYBRID)	3.70	**11.35**	**21.94**	**27.87**	**30.97**
SHASTA, CXD 109	3.69	1.28	0.46	1.77	3.32
SPECTRUM 579 (PSX 57994)	3.54	2.71	0.92	0.92	0.05
LA ROSSA, NVH 4762	3.47	**5.63**	4.55	3.12	0.82
NEMA 1400	3.40	2.66	0.84	0.54	0.13
SAUSALITO, PSX 7090	2.50	0.88	-----	0.02	-----
NEMA 1435 (PSX 3594)	2.09	2.62	1.44	1.25	0.81
APEX FM 1000	2.04	1.55	1.13	1.75	0.23
E 6203 (FM)	1.84	1.32	1.63	0.59	0.14
NEMA 1200	1.69	**2.68**	1.03	0.44	0.28
LASSEN, CXD 101	1.51	0.65	0.04	-----	-----
H 2710	1.43	2.59	1.17	1.48	-----
YUBA, FM 48432	1.36	**1.48**	0.94	0.00	0.03
CASTELPEEL 2, EARLY CASTLEPEE	1.16	-----	-----	-----	-----
PEELMECH, E 9208 (FM)	1.05	0.80	0.60	0.10	-----
QUICKIE, PGI 1101	0.93	0.09	-----	-----	-----
UC 82 (ALL TYPES)	0.80	0.31	-----	0.03	0.08
UC 204-C (PS)	0.79	-----	-----	0.03	0.01
ALLEGRO, H 5211	0.78	-----	0.07	-----	-----
Total	87.98	81.30	72.27	67.90	49.03

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summaries for 1991-1995.

[a] The percentages in bold type indicate that the percentage share of the variety increased from the previous year.

load share in San Joaquin county each year, albeit not as rapidly as in Yolo county (Table 4.12). In Fresno county, five of the top ten varieties were OPs during 1991, including the number one variety FM Apex 1000, which held a 10.36 percent load share. By 1995, the load shares of each of the top five OPs had fallen, but were still all above 1 percent. This may indicate that growers in Fresno county are less dependent on hybrid varieties than growers in Yolo and San Joaquin counties (Table 4.13).

IV.4. Amount of Control Processors Exert Over Variety Selection:

For many years, growers were free to grow whichever varieties they desired since there was strong demand for raw tomatoes and the price paid to growers was high by historical standards. For example, during the early 1970s growers were paid over three times as much per ton (in inflation adjusted dollars) as growers currently receive. When processors gained control over variety selection during the early 1980s, the emphasis shifted from planting high yielding varieties to planting varieties that incorporate many of the traits demanded by processors [Orsetti--personal communication].[17] Processors either specify precisely which varieties their growers can purchase, or they provide growers with variety lists that give them a limited number of varieties to choose from. They usually give growers several alternative varieties since a variety that works well for one grower may do poorly for a neighboring grower [Lomanto--personal communication].

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[17] The ultimate processor variety would require 115 days to mature, have high soluble solids and high viscosity, a jointless pedicel, excellent multi-use potential, hold extremely well and be hard and firm [Kennedy--personal communication].

Table 4.12. San Joaquin County Load Share Changes Between 1991 and 1995 for the Twenty-Five Varieties with the Largest Load Shares During 1991

Top 25 Varieties Harvested During 1991	Share of Delivered Loads				
	1991	1992	1993	1994	1995
	Percent				
PEELMECH, E9208 (FM)	14.26	9.12	4.93	2.56	1.66
E 6203 (FM)	9.93	3.04	2.23	0.61	0.02
BRIGADE, H 5210	9.40	**12.58**[a]	11.48	6.39	4.51
UC 82 (ALL TYPES)	5.54	3.77	**4.41**	2.16	0.00
NEMA 1401	4.50	2.93	**3.19**	1.62	1.16
H 2710	4.34	3.15	1.73	0.43	-----
NEMA 512	4.09	**7.47**	**7.90**	6.40	3.65
ALTA, CXD 100	3.95	1.09	0.13	0.61	0.23
H 8773	3.62	3.04	1.03	0.14	0.79
SUN 1642	3.55	**5.47**	**5.78**	4.14	3.84
BOS 3155 (HYBRID)	3.40	**5.10**	**7.84**	**15.08**	**16.80**
KS 5715 (AV, AG, SUNSEED)	3.20	**7.86**	5.55	4.54	1.37
H 8768	3.10	**5.30**	4.35	4.22	1.93
FMX 785 (E 0204)	2.48	2.44	0.80	0.58	-----
DIEGO, HM 3075	2.35	**3.35**	1.20	-----	-----
APEX FM 1000	2.32	1.80	0.58	0.07	-----
P 111B	1.55	1.41	**1.98**	1.37	0.79
NVH 4761 (5-7317)	1.44	0.06	-----	-----	-----
H 3044	1.38	1.10	1.39	1.29	-----
H 3302	1.35	1.12	0.93	0.21	0.14
NEMA 1400	1.30	**3.48**	1.69	0.48	-----
H 282	1.23	**3.24**	**3.67**	3.66	2.47
LASSEN, CXD 101	1.21	0.01	0.11	-----	0.00
LA ROSSA, NVH 4762	1.06	**2.65**	2.19	2.43	2.23
NVH 4764 (5-7426)	0.77	0.32	0.13	0.37	0.01
Total	91.32	90.90	78.89	59.36	41.60

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summaries for 1991-1995.

[a] The percentages in bold type indicate that the percentage share of the variety increased from the previous year.

Table 4.13. Fresno County Load Share Changes Between 1991 and 1995 for the Twenty-Five Varieties with the Largest Load Shares During 1991

Top 25 Varieties Harvested During 1991	Share of Delivered Loads				
	1991	1992	1993	1994	1995
	----------Percent----------				
APEX FM 1000	10.36	9.58	8.45	5.97	1.78
E 6203 (FM)	10.27	5.78	5.15	4.11	1.86
BRIGADE, H 5210	8.13	6.54	**7.28**[a]	7.04	3.96
PEELMECH, E 9208 (FM)	6.40	**9.08**	5.08	4.74	2.82
KS 5715 (AV, AG, SUNSEED)	5.64	4.90	4.83	3.03	2.30
NEMA 1200	4.56	2.27	**2.91**	1.72	1.76
SUN 1642	4.02	2.59	**3.48**	2.00	**1.30**
GS 12	3.38	**3.65**	0.97	0.41	**0.76**
NEMA 512	3.29	2.89	**4.18**	**4.41**	2.81
ALTA, CXD 100	3.10	2.38	0.36	**0.50**	0.19
BOS 3155 (HYBRID)	3.06	**9.41**	**15.75**	**18.69**	**19.52**
LA ROSSA, NVH 4762	2.96	**4.41**	3.13	**4.34**	**5.58**
H 2710	2.12	**2.57**	1.52	1.39	1.00
P 111B	2.10	**2.68**	**3.43**	2.50	1.29
DIEGO, HM 3075	2.07	1.70	0.04	-----	0.03
FMX 785 (E 0204)	1.83	0.97	0.52	0.45	0.30
UC 204 (ALL TYPES)	1.69	0.00	0.17	-----	-----
NEMA 1401	1.48	0.98	**1.34**	0.08	0.02
NVH 4771 (5-7115)	1.44	**2.75**	0.49	-----	-----
H 8773	1.39	**1.52**	0.48	0.31	0.09
HEINZ 1916	1.34	**1.41**	-----	0.06	0.04
SUNRE 6066	1.01	0.23	0.02	-----	0.11
DEL ORO, MOX 3076	0.94	0.41	0.39	**0.41**	-----
NEMA 1400	0.94	0.82	0.56	0.11	**0.19**
UC 82 (ALL TYPES)	0.92	0.24	0.32	0.10	**0.11**
Total	84.44	79.76	70.85	62.37	47.82

Source: Processing Tomato Advisory Board: Average Defects by Variety--Annual Summaries for 1991-1995.

[a] The percentages in bold type indicate that the percentage share of the variety increased from the previous year.

Processors include anywhere from five to sixty varieties on their approved variety lists. Many of the lists are divided into separate categories depending on the type of products the processor specializes in. For example, the processor may have three different categories, one for whole peel, a second for dice and a third for paste varieties [Brown--personal communication]. In addition, the lists frequently include early, mid and late season varieties to enable the canneries to run at or close to capacity throughout the harvest [May--personal communication]. Within each category there are usually several varieties to choose from. Each category also may include one or two experimental varieties that processors encourage growers to plant on a few acres [Brown--personal communication]. Some processors allow growers to freely select varieties from each category.[18] Other processors specify the percentage of each grower's acreage to be planted with one or more of the varieties included on the approved variety list.[19] Each year the lists are modified to include new and improved varieties and to keep pace with changes in consumer preferences. For example, in recent years there has been a dramatic increase in the demand for slice and dice products. As a result, many processors have shifted toward the use of slice

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[18] For example, Stanislaus Food gives its growers two different lists of varieties to choose from. One is a list of square varieties while the other is a list of pear varieties. Each list contains between six and eight varieties [Gill--personal communication].

[19] Campbell is very concerned about how its products taste. To ensure uniform taste it uses a specific variety program for the production of cold and hot-break tomato paste. Growers are provided with a list that contains eight to nine varieties for cold-break tomato paste, and a list of fourteen varieties for hot-break tomato paste. Since Campbell wants to purchase a specific percentage of each variety, it asks each grower to produce a specified number of tons of one or more of the varieties included on its approved variety list [Kuehn--personal communication].

and dice varieties such as Brigade and Heinz 8892 [Angell--personal communication].[20]

Most processors tend to include at least one popular variety on their approved variety lists to increase their flexibility. In recent years, the most popular hybrid variety has been BOS 3155 which is produced by the Orsetti Seed Company.[21] It is popular among processors because of its high soluble solids which makes it well suited for paste. It is also firm and has excellent color which are important characteristics of whole peel and diced tomatoes [Orsetti--personal communication].[22] Processors like BOS 3155 although it doesn't have the best taste or peelability and ranks only eighth for soluble solids and seventh for firmness. However, its soluble solids average 5.43 which is higher than the state average of 5.24 [Hirahara--personal communication]. Processors also like BOS 3155 because the stem falls off easily before it reaches the plant which is important for whole peel products [Nichols--personal communication].

The Morning Star Packing Company provides growers with an approved variety list that allows growers much more freedom to choose varieties than other processors. If one of its customers desires paste with 31 percent soluble solids and medium viscosity, Morning Star uses different varieties than it uses to produce paste

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[20] Processors want slice and dice varieties that have a thick wall, deep red color and are consistent so that the slices will be clear and concise. They also prefer varieties with soluble solids that is a little higher than average [Lomanto--personal communication].

[21] During 1995, BOS 3155 accounted for slightly over 22 percent of delivered loads [PTAB data].

[22] Fifty percent of the salsa sold in the United States contains the BOS 3155 variety [Orsetti--personal communication].

with 31 percent soluble solids and high viscosity.[23] Hence, to satisfy different customer objectives, it divides its variety list into four different categories. The list includes some varieties with high soluble solids, some with high viscosity and others with high yields. The list also includes incentives and deductions for each variety.

If a grower selects a high yielding variety with low soluble solids, he may receive $10 less per ton than he would receive for other varieties. On the other hand, if he selects a somewhat lower yielding variety with high soluble solids, he may receive an incentive of $2 per ton.[24] The deductions and incentives are designed to enable Morning Star to minimize its production costs while obtaining the mix of soluble solids, viscosity and color it needs to make quality paste.[25] If it needs to produce paste with four or lower bostwick, it uses varieties that are included in group one.[26] Within that group, a grower can choose to grow Yuma and earn an incentive of $5 per ton, or NK4754 and suffer a deduction of $11 per ton.[27]

A grower may still choose to plant one of the high yielding varieties included on the Morning Star approved variety list despite the lower price. The grower may believe his cultural practices, soil and climate are particularly well suited to the

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[23] Customers who plan to produce catsup want very thick paste [Rufer--personal communication].

[24] For example, growers are docked as much as $10 per ton for growing some Heinz varieties and are paid an incentive of $2 per ton if they grow the Vega variety [Jacobs--personal communication].

[25] Morning Star also uses data obtained from inspection stations to deduct for poor quality [Merwin--personal communication].

[26] The varieties included in group 1 have lower soluble solids. Ideally, the varieties included in group 1, have soluble solids that range between 5.2 and 5.3 percent [Rufer--personal communication].

[27] Regardless of the bostwick level of the paste produced, processors are paid the same amount of money by their customers since paste is considered to be a single commodity [Rufer--personal communication].

variety and will produce enough tons to compensate for the deduction. However, the deductions for some varieties are so high that growers who select them commit economic suicide [Yerxa--personal communication]. As a result, some growers believe that although competing processors provide growers with fewer choices than Morning Star, they offer more flexibility [Fawcett--personal communication].

IV.4.1. Processor Criteria for Developing Variety Lists:

Processors attempt to match their processing needs to the biological limitations of the varieties included on their approved variety lists. They also attempt to select varieties and acreage that are compatible with their growers' harvesting capacity, cultural practices, climate, soils and the varieties their growers have contracted to produce for other processors [Lomanto--personal communication]. Since there is no one variety that contains the perfect mix of paste characteristics, processors frequently blend the raw product obtained from a wide range of growers and varieties. They arrange to harvest the varieties at the same time and blend them to obtain the desired product [Brown--personal communication]. For example, there may be one variety that produces high viscosity but has poor color, while another variety may have good color but poor viscosity. Some growers produce better color due to their soil and weather, while others produce higher soluble solids. Thus, processors may require growers to use certain varieties in one part of California, and a different set of varieties in another part of the state.[28] They also may ask a specific grower to use

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[28] Tri-Valley divides the state into growing districts and each district is given a different list of suitable varieties [Tarry--personal communication]. Tri-Valley wants varieties that peel well--including pear shape, have good color and multi-use potential so they can be used to make high quality paste

certain varieties if there is something about his cultural practices which meshes well with the varieties.

IV.4.2. Processor Variety Choices Depend on Products Produced:

Since processors produce a range of products and attempt to fill various market niches, they use a wide range of similar and dissimilar varieties. Some processors only produce paste, while others produce a combination of whole peel, dice and paste products. A variety that works well for the production of one product may be unsuitable for the production of a different product. In addition, two processors who manufacture the same product may use different varieties due to differences in processing technology, manufacturing techniques, seasonal variations, and differences in their knowledge of the strengths and weaknesses of different varieties.[29]

Whole peel processors prefer varieties that stem easily, are durable enough to survive the trip to the processing plant, do not become mushy when peeled and have high enough soluble solids to be used for paste [Turkovich, Nichols--personal communication]. Paste producers, on the other hand, are much more interested in soluble solids and viscosity. Two types of paste products are manufactured: cold and hot break. Most processors, with the notable exception of Campbell, produce hot

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[Hirahara, Jacobs--personal communication].

[29] Some of the canneries which use older equipment, are unable to process highly viscous varieties because their pumps are unable to push the thicker puree through the pipeline. It can also burn out the pipeline and clog-up the entire cannery. Some of the canneries, such as Morning Star, have modern equipment that can handle more viscous varieties [Nichols--personal communication].

break tomato paste [Kuehn--personal communication]. Hot break tomatoes are first pureed and then cooked to 212 degrees fahrenheit. Cold break tomato paste is cooked to roughly 155 degrees fahrenheit and is made with varieties that are characterized by higher soluble solids, relatively lower viscosity and a lower pH than the varieties used to produce hot break paste [Jacobs--personal communication].[30]

Approximately 70 percent of processing tomatoes are used to produce paste. This partly occurs because many tomatoes lack sufficient quality to be used for other purposes like whole peel and diced products.[31] Some processors prefer to produce paste for one of two reasons. First, they have modern equipment which has narrowed and possibly eliminated the profitability gap between paste and other tomato products.[32] Second, some canneries prefer to produce paste since they earn value added profits from reconstituted paste products such as sauces and catsup.[33]

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[30] If the processor intends to make hot break tomato paste it can use early maturing varieties since they tend to have higher bostwick. If it is interested in cold break paste it may use a mid-season variety which will have better color [Woolf--personal communication]. Botulism may develop in cold break tomatoes if the pH is too high [Pruett--personal communication]. The lower temperature is compensated for by using varieties with a lower pH--in the range of 4.2-4.3--rather than 4.5, which is the average for most varieties [Jacobs--personal communication].

[31] For example, a variety that has yellow shoulders can be used for paste but not for peeling [Petz--personal communication].

[32] It is very difficult for Stanislaus to earn profits from paste production since it uses older equipment [Petz--personal communication]. However, some processors must earn money from paste since within the past five years four to five new paste canneries have come on line [Pruett--personal communication]. Some of the plants with new equipment are owned and operated by Heinz or by The Morning Star Packing Company [May--personal communication].

[33] This includes processors like Heinz, Hunts and Contadina Foods that use paste to produce other products such as catsup [Rufer--personal communication].

IV.4.3. Impact of Proprietary Varieties on Variety Lists:

Processors including Campbell, Van den Bergh Foods and Heinz develop their own varieties to provide a differential quality advantage for their own pack and to earn profits via seed sales. Thus, some variety lists are affected by processors who require their contracted growers to plant most of their acreage with in-house proprietary varieties. Although they are primarily interested in breeding varieties to satisfy their own processing requirements, processors spread their fixed costs over more units by selling seed on the outside market [Stewart and Storz--personal communication]. However, they may restrict the sale of some of their better varieties to their own growers [Kuehn--personal communication]. The market share of seed dealers is adversely affected by proprietary varieties since it reduces the number of varieties they are able to sell [Stewart and Storz--personal communication].

The most widely used proprietary varieties are produced by Heinz. Over the past few years the popularity of its proprietary varieties has increased rapidly. Between 1994 and 1995, the share of Heinz varieties increased from 17 percent to 30 percent of total production [Pruett--personal communication]. Consequently, fifteen of the top fifty varieties are currently produced by Heinz [Rufer--personal communication].[34] Since it requires its contracted growers to grow Heinz varieties, and since it processes approximately 10 percent of total raw tomato production, it is able to exert a major impact on seed sales [Stewart and Storz--personal communication]. Heinz prefers to process its own varieties because they were bred to

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[34] Many of the Heinz varieties are also sold on the open market to growers who do not produce for Heinz [Rufer--personal communication].

have high viscosity and excellent color which are needed for catsup production [Pruett--personal communication].

Heinz varieties also are popular with non-Heinz growers since they produce very high yields, have good multi-use potential (such as Heinz 8892), have compact vines, set well and mature evenly [Merwin, Robertson--personal communication]. They also are popular since many of the Heinz varieties mature early. Early maturing varieties were needed during 1995 due to heavy rains which delayed planting. Other processors such as Hunts, Contadina and Colusa Canning also prefer to use Heinz varieties since their production objectives are similar to those of Heinz [Stewart and Storz--personal communication].

Unlike Heinz, Campbell is more interested in producing varieties with high soluble solids since it reduces the cost to produce paste. Campbell, unlike other processors, also desires varieties with low acidity since it affects the taste of its soups and juices.[35] As a result, its varieties are less appealing to other processors, and consequently its varieties comprise less of the seed market than Heinz varieties [Stewart and Storz--personal communication]. Campbell varieties also comprise less of the seed market since they are less appealing to growers. For example, one of Campbell's varieties called CXD 152 had the tenth largest statewide load share during 1995. However, it is unpopular among growers since they claim it tends to get moldy and has very poor field holding. Growers are only willing to grow the variety

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[35] However, Campbell is also interested in some high viscosity varieties for use in products like Prego Spaghetti sauce.

if Campbell also allows them to grow other higher yielding varieties [Jacobs--personal communication].

IV.5. Amount of Control Growers Exert Over Variety Selection:

Half of the growers surveyed indicated that processors permit them some control over variety selection. Over 35 percent indicated they have considerable control over variety selection while 10.5 percent indicated they have no control (Table 4.14). However, some of the regional percentages were significantly different. Over 70 percent of the growers in Regions III-V indicated they have some control over variety selections, while 42.2 percent of the growers in Region I indicated they have considerable control. Different sized growers expressed very little variability in the amount of control they are able to exert over variety selection. Approximately half of the growers indicated they have some control over variety selections while one-third indicated they have considerable control (Table 4.15). One third of the growers indicated they are permitted to choose between six and ten different varieties per processor. Approximately 15 percent of the growers indicated they can choose between eleven and fifteen different varieties per processor (Table 4.16). In addition, growers with large farms tend to have more variety choices (Table 4.17).

IV.5.1. Methods Growers Use to Increase Variety Choices:

Although processors attempt to limit the number of varieties growers can choose, growers are able to increase their variety choices in many different ways. One way is by selling their production to several processors. This increases their

Table 4.14. Grower Estimates of the Amount of Control They are Permitted by Processors to Exert Over Variety Selection, by Region

Control Permitted by Processors	Grower Regional Control Over Variety Selection			
	Region I	Region II	Regions III-V	State
	----------Percent----------			
None	11.1	8.3	14.3	10.5
Some	40.0	62.5	71.4	50.0
Considerable	42.2	29.2	14.3	35.5
Complete	6.7	0.0	0.0	3.9

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

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Table 4.15. Grower Estimates of the Amount of Control They are Permitted by Processors to Exert Over Variety Selection, by Farm Size

Control Permitted by Processors	Grower Control Over Variety Selection by Farm Size[a]			
	Small Farms	Medium Farms	Large Farms	State
	----------Percent----------			
None	9.1	17.6	10.5	11.6
Some	48.5	47.1	57.9	50.7
Considerable	33.3	35.3	31.6	33.3
Complete	9.1	0.0	0.0	4.3

Source: Mail survey of processing tomato growers conducted between October, 1995 and January, 1996.

[a] Small farms are defined as having 500 or fewer acres. Medium sized farms are defined as having between 501-1000 acres while large farms are defined as having 1000 or more acres.

Table 4.16. Grower Estimates of the Number of Processing Tomato Varieties They are Permitted to Choose from Processor Approved Variety Lists, by Region

Number of Variety Choices Permitted by Processors	Impact of Region on Grower Ability to Choose Varieties			
	Region I	Region II	Regions III-V	State
	----------Percent of Grower Responses----------			
0	0.0	8.3	14.3	4.0
1-5	22.7	20.8	57.1	25.3
6-10	36.4	33.3	28.6	34.7
11-15	15.9	16.7	0.0	14.7
16-20	13.6	16.7	0.0	13.3
21-30	4.5	0.0	0.0	2.7
31-40	2.3	0.0	0.0	1.3
41-50	4.5	4.2	0.0	4.0

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996

Table 4.17. Grower Estimates of the Number of Processing Tomato Varieties They are Permitted to Choose from Processor Approved Variety Lists, by Farm Size

Number of Variety Choices Permitted by Processors	Impact of Farm Size on Grower Ability to Choose Varieties[a]			
	Small Farms	Medium Farms	Large Farms	State
	---------Percent of Grower Responses---------			
0	3.1	5.9	5.3	4.4
1-5	34.4	23.5	10.5	25.0
6-10	31.3	47.1	42.1	38.2
11-15	9.4	11.8	10.5	10.3
16-20	18.8	5.9	15.8	14.7
21-30	0.0	0.0	5.3	1.5
31-40	0.0	0.0	5.3	1.5
41-50	3.1	5.9	5.3	4.4

Sources: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Small farms are defined as having 500 or fewer acres. Medium sized farms are defined as having between 501-1000 acres while large farms are defined as having 1000 or more acres.

variety choices since each processor has different variety requirements. For example, varieties grown for Del Monte have different characteristics than the varieties grown for Ingomar which only manufactures paste [Pruett--personal communication]. In northern California, most of the growers contract with four or five different processors. In southern California, growers may sell to only three or four processors since some of the large ranches have built their own processing plants [Kennedy--personal communication]. One ranch built its own cannery to gain control over production and to avoid excessive losses due to high limited use and other defects [Woolf--personal communication].

There are several other reasons why growers generally sell their production to more than one processor. First, if a processor is running at full capacity, or is having machinery problems, it enables growers to trade their production back and forth between different processors [Herringer--personal communication].[36] Second, by selling to multiple processors, growers increase the likelihood of being able to sell their excess production [Mullen--personal communication].[37] Third, growers select canneries based on location. There is a strong correlation between the distance the tomatoes are transported and the size of the deductions [Robertson--personal

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[36] Processors attempt to contract for tons from each grower based on their track record. Thus, if a grower averages 28 tons per acre across varieties, the processor will frequently only contract for the equivalent of 25 tons per acre to make certain they obtain the tons they need [Gill--personal communication].

[37] If a grower contracts to produce 3000 tons on 90 acres but ends up producing 5000 tons, the excess tonnage can be sold by the grower at the prevailing market price. Some varieties are easier to sell than others. In some years the price may be very high while in other years it may not justify the harvest cost. For example, during 1994 demand was strong and almost all of the excess production was sold at the base price. Several years earlier, processors purchased excess tonnage at $15 below the base price [Rivara--personal communication].

communication]. If a grower's farm is far from the nearest cannery, he may prefer to plant varieties with superior field holding. Fourth, most processors are unwilling to sign a contract for all of a grower's production since it exposes them to too much risk [Mast, Kennedy, Brown--personal communication].[38] Fifth, since each processor produces somewhat different products, growers are able to broaden their variety choices. For example, one grower sells 75 percent of his production to Heinz which it uses to manufacture paste, and 25 percent to Sungarden which it uses to manufacture salsa and whole peel products [Robertson--personal communication].[39] Sixth, if a grower is not offered a new contract by one of his processors, he may be able to shift production to the remaining processors.[40]

Growers also are able to widen their variety choices if processors' demand for raw tomatoes exceeds their projected supply (including carryover). This forces them to allow growers to select higher yielding varieties with fewer desirable processing traits [Jacobs--personal communication]. Another method growers use to increase their variety choices is by attempting to exert some control over the selection of

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[38] Processors are unwilling to take all of a large growers production because, if for some reason the crop fails, the processor needs to be able to obtain tomatoes from other growers to reduce its risk and uncertainty [Brown--personal communication].

[39] Many growers indicated that they do not know and do not care what their production is used for. They are only interested in being paid for the tons they produce. Growers are primarily interested in planting high yielding varieties that will suffer minimal deductions at the inspection stations [Turkovich--personal communication]. Other growers are very interested in the end use of the varieties they sell since processors who are able to increase their market share, and maximize their returns, are able to pay growers more in the form of incentives [Herringer--personal communication]. [39]

[40] It is oftentimes difficult for growers to get contracts. Processors usually work with the same group of growers from one year to the next. A grower may prefer to sell to one processor more than another, but he may be unable to get the desired contract. For example, a grower may prefer to grow for a nearby cannery since a cannery located far away may decide to stop offering a contract to save on freight costs [Turkovich--personal communication].

varieties included on processors' approved variety lists. For example, Campbell now allows growers to plant 20 percent of their acreage with BOS 3155 partly because of grower pressure [Herringer--personal communication].[41] Tri-Valley sometimes allows growers to select a variety that is not included on their variety list if it fits-in with their marketing plan [Tarry--personal communication]. Growers also influence processor variety lists by refusing to plant poor yielding varieties [May--personal communication]. Several years ago growers in the southern part of California grew a Harris Moran variety called Murrieta. At first growers were very happy with the variety because it yielded 40 tons per acre. However, when yields fell to as low as 18 tons per acre, growers refused to plant it the following year [Petz--personal communication].

However, the amount of influence growers exert over the selection of approved varieties is limited since there are some varieties that processors will absolutely not accept. For example, they will not permit growers to use a variety if it causes their case yield to fall by 10 percent [Timothy--personal communication]. In addition, processors may allow a variety to be used in one part of the state but not in another part if it is highly sensitive to growing conditions. For example, FM Apex 1000 performs beautifully in Fresno county but adapts very poorly in the northern part of the state [Rivara--personal communication]. Ingomar only allows its growers to use specific varieties since the paste it produces must have specific quality attributes to satisfy its customers [Pruett--personal communication]. Consequently, it

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[41] However, Campbell first made certain that the variety fit-in well with its processing operation. Campbell's decision was made easier by its purchase of Pace which manufacturers salsa--which requires good dicing varieties like BOS 3155 [Herringer--personal communication].

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is not too surprising that the results of the grower survey revealed that 89 percent of the growers would include more high yielding varieties on processor variety lists, 67 percent would include more varieties with improved field holding, while 50 percent indicated they would include more varieties with improved disease resistance (Table 4.18).

IV.5.2. Grower Criteria for Variety Selections:

Growers base their variety choices on a number of different factors. First, they recall their own experiences with certain varieties which includes an evaluation of the number of tons each variety yielded per acre and its average incentives and deductions. If growers believe the yield and quality of a variety fell relative to other varieties, they seek alternatives and attempt to convince processors to use other varieties. Second, growers base their variety choices on the approved variety lists processors provide to their contracted growers. Third, they review the results of field trials conducted by the California Cooperative Extension Service.[42] They also

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[42] Each year the California Cooperative Extension Service conducts extensive replicated and non-replicated variety trials in several counties in the Central Valley of California. The counties include: Yolo, Colusa, San Joaquin, Stanislaus and Fresno counties. The varieties tested are chosen by the Cooperative Extension Service in conjunction with processor and seed company input. Traditionally, varieties are first evaluated in non-replicated trials before advancing to replicated blocks. Typically, varieties included in replicated trials are evaluated for three years. Several varieties also are used as standards against which the other varieties are compared and contrasted. The variety evaluations are divided into early, mid and late maturing trials. For the most part, the varieties are direct seeded on soil of similar quality which is irrigated. The trials are conducted on selected growers' fields and use the cultural practices of the cooperating grower. After the yield is recorded, a small sample of the fruit is sent to a local inspection station run by PTAB to measure quality attributes. Additionally, samples are submitted to the UC Davis Food Science and Technology Department to measure viscosity (bostwick units) [University of California Cooperative Extension].

Table 4.18. Grower Estimates of the Degree to Which Selected Factors Would Cause Them to Choose Different Varieties Than Processors, by Region

Selected Factors	Proportion of Growers Who Selected Each Factor			
	Region I	Region II	Regions III-V	State
	----------Percent of Grower Responses----------			
Field Holding	62	79	57	67
Yield	82	100	100	89
Disease Resistance	56	42	43	50
Stress Tolerance	22	29	29	25
Maturity Length	38	33	57	38
Lower Deductions	33	29	29	32

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

consider technical advice obtained from seed companies, seed dealers, processors and farm advisors; potential risk and uncertainty, compatibility with their cultural practices, seed prices and regional soil and climatic conditions. Surveyed growers indicated that the most important information source they use to choose varieties is their own experience. This was followed by processor supplied data, variety trials, seed dealers, other growers, PTAB data and seed companies (Table 4.19).[43]

Growers also indicated that when they select newly released varieties, the most important factors are yield potential, field holding, processor preferences and disease resistance. Other factors including stress tolerance, maturity length and deductions play a less important role in the choice of new varieties (Table 4.20).

IV.5.3. Role of Grower Experience in Selecting BOS 3155:

During 1995, and several previous years, BOS 3155 comprised the largest statewide share of inspected loads. It is popular with many growers although it has no Bacterial speck or nematode resistance and is not the highest yielding variety. However, it has excellent color, above average soluble solids, firmness, holds extremely well, and it can be grown in most of the California micro-climates and on most soil types. This includes soils that normally produce poor yields. It also is an excellent dicing tomato [Angell, Rivara--personal communication].[44] In addition,

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[43] Although growers indicated that variety trials are less important than their own experience and processor supplied data, field trial data is used extensively by processors, seed dealers and seed companies. Without field trial data it would be difficult or impossible for processors to develop their approved variety lists. In addition, growers would have much less information to make informed decisions regarding which new varieties to purchase [Ward--personal communication].

[44] Most growers are not concerned that BOS 3155 lacks Bacterial speck resistance since it is not planted early when Bacterial speck is a major problem [Turkovich--personal communication].

Table 4.19. Grower Estimates of the Impact of Information Sources on Grower Selections of Processing Tomato Varieties

Information Sources	Importance of Varietal Information By Growing Region			
	Region I	Region II	Regions III-V	State
	---------Grower Ranking of Information[a]---------			
Varietal Trials	3.39	3.38	2.71	3.32
Seed Dealers	2.64	3.27	1.86	2.77
Processors	4.13	3.96	3.71	4.04
Other Growers	3.07	3.41	2.71	3.14
PTAB Data	2.23	2.72	2.17	2.37
Seed Companies	2.39	2.90	2.29	2.55
Own Experience	4.51	4.54	4.71	4.54

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] Growers ranked the importance of each trait from 1 to 5. A ranking of 5 indicates that the factor is very important while a ranking of 1 indicates that the factor is unimportant.

Table 4.20. Grower Ranking of Factors That Have Influenced Their Adoption of Newly Introduced Processing Tomato Varieties Over the Past Five Years

Adoption Factors	Importance of Adoption Factors by Growing Region			
	Region I	Region II	Regions III-V	State
	----------Grower Ranking of Factors[a]----------			
Field Holding	4.51	4.24	4.43	4.42
Yield	4.84	4.86	4.71	4.83
Disease Resistance	4.14	3.80	4.29	4.05
Stress Tolerance	3.43	3.25	3.86	3.42
Maturity Length	3.20	3.20	3.71	3.25
Lower Deductions	3.95	3.85	4.14	3.94
Processor Requested	4.48	4.22	4.14	4.36

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

[a] The factors were ranked from 1 to 5. A ranking of 5 indicates that growers considered the trait to be very important while a ranking of 1 indicates that the factor is not important.

most processors are willing to purchase excess production of the variety [Hirahara--personal communication].

Other growers have experienced problems with BOS 3155 and prefer not to use it. One grower found that although it has excellent holding, yield is inconsistent from one year to the next. Another grower commented that he has had only limited success with BOS 3155 because the vine is too large for use in double row planting [Robertson--personal communication]. A Delta region grower commented that by the time BOS 3155 develops good color, mold problems have developed since the nights have become cool and dew is beginning to form on the plants. This significantly lowers the usable yield [Merwin, Woolf--personal communications].[45] Another grower stated that he is unable to use BOS 3155 because all of his soil has nematodes [Fabbri--personal communication].

In addition, due to the long maturation required for BOS 3155 (128 days), some acreage was planted with alternative varieties during 1995 due to the early season rain which delayed planting [Petz, Turkovich--personal communication]. As a result, some growers prefer to plant Brigade, although it does not hold as well as BOS 3155, since it matures somewhat sooner [Timothy--personal communication]. Finally, growers in the southern growing region of California, use less BOS 3155 than in the north, because it matures after most of the region's processing tomato acreage has been harvested [Hirahara--personal communication].

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[45] The heat units in the Delta region are much lower than in other tomato growing regions because of cool ocean breezes [Merwin--personal communication]. BOS 3155 doesn't do well in areas with a cool spring and summer since it slows down the maturation process. This is not well suited to a long maturing variety like BOS 3155. As a result, growers plant other varieties that are less temperature sensitive [Lomanto--personal communication].

IV.5.4. Role of Deductions in Grower Variety Selections:

Deductions play a major role in growers' variety choices. Many growers are willing to give a variety a second chance if it suffered high deductions one year, especially if the variety's yield more than compensated for lost revenues [Merwin--personal communication]. Some growers continue to plant a variety for two to four years before making a change, because the high deductions may have occurred for reasons that had nothing to do with the variety. For example, they may have been caused by insects, irrigation breakdowns, management problems or by unusual weather patterns [Merwin--personal communication]. In addition, growers prefer to gradually change varieties since each variety requires specific cultural practices which involve the proper use of water and fertilizer. The cultural practices have to be relearned every time the varieties are changed. It usually requires one year to observe a new variety and a second year to see how well it responds to different growing conditions before growers feel completely comfortable with it [Fabbri--personal communication].

However, if one or more varieties fare particularly poorly due to high temperatures or rainfall, growers may replace them much sooner [Herringer--personal communication]. Growers usually will experiment with several new varieties in the hope of identifying one or more that are likely to suffer lower deductions than the varieties they are currently using, while still producing comparable or improved yields [Petz--personal communication].[46] Some growers divide their high deduct varieties

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[46] One of the major causes of high deductions is poor field holding. Growers tend to replace varieties with poor field holding with varieties such as BOS 3155 and Brigade that hold in the field much longer.

into several blocks to minimize the risk of having an entire variety go soft due to harvest delays [Robertson--personal communication].

Two years ago Harris Moran sold over $1 million worth of seed for a variety called Vega. The variety was popular since it has high viscosity and acidity which makes it an excellent paste tomato. However, this past year the company sold only $2 thousand worth of the seed since during an earlier season, Vega tomatoes became very moldy when they were harvested at the end of September. As a result, some of the tomato loads were rejected by the state inspection stations since they exceeded the state mold limit of 5 percent. Although most of the loads were not rejected, growers were still unhappy with the variety since moldy fields force them to slow down their harvesters to remove the moldy tomatoes before the loads are inspected. In addition, the higher mold content increased grower deductions at the cannery. Thus, although many processors like Vega, they realize that growers are unwilling to use the variety and have removed it from their approved variety lists [Jacobs--personal communication].

IV.5.5. Role of Seed Price in Grower Variety Selections:

In many instances the price of seed has little bearing on which varieties growers choose to grow. This is especially true if the processor approved variety list is very restrictive [Mullen, Turkovich--personal communication]. Processors believe that growers are willing to pay high prices for varieties if they make up for it in higher yields [Gill--personal communication]. One grower indicated that if a processor provides him with a choice of two varieties that are equal in every

imaginable way except price, he may choose to plant slightly more of the cheaper variety [Petz--personal communication]. Twenty-five percent of the growers surveyed indicated that the seed price has no influence on their selection of varieties. However, 63 percent indicated that the price has some influence, and 12 percent indicated that the price strongly influences their variety purchases (Table 4.21).

Oftentimes, the decision of which varieties to purchase is determined not by price, but by the adaptability of the variety to specific climatic and soil conditions. For example, BOS 3155 has such excellent field holding and other characteristics that growers are sometimes willing to pay 20 to 40 percent above the suggested retail price [Nichols--personal communication]. Although Heinz seed prices are high compared to the seed prices of some of the other seed companies, growers purchase them because the varieties are very high yielding and have other good qualities [Mast--personal communication]. At the same time, if a variety has one or more major deficiencies, growers are usually unwilling to purchase the seed even if it is priced substantially lower than other varieties [Turkovich--personal communication].

When the choice is between two hybrids that differ in cost by only $20 or $30 per 100 thousand seed unit, the price difference is not a factor for some growers. However, one grower indicated that if the price difference between two very similar varieties was only 10 percent he would purchase the variety that he knew from experience was the most consistent and adaptable [Fabbri--personal communication]. When the choice is between an OP and a hybrid which costs many times more, price plays a more important role [Remonda--personal communication]. However, much of the price difference between hybrids and OPs is more imaginary than real. Although

Table 4.21. Grower Estimates of the Regional Impacts of Seed Prices on Grower Selections of Processing Tomato Varieties

Influence Level	Importance of Seed Prices by Growing Region			
	Region I	Region II	Regions III-V	State
	----------Percent----------			
No Influence	34.1	8.3	28.6	25.3
Some Influence	59.1	70.8	57.1	62.7
Strongly Influences	6.8	20.8	14.3	12.0

Source: Mail survey of California processing tomato growers conducted between October, 1995 and January, 1996.

hybrid seed is much more expensive than OP seed, the cost of seed used to produce one ton of tomatoes has increased by much less than it appears. Growers generally plant half as many hybrid seeds as OP seeds per acre. In addition, average hybrid yields tend to be five to ten tons higher per acre than the average OP yields [Storz--personal communication].[47]

Growers carefully examine the qualitative and quantitative differences between the varieties included on processor approved variety lists if there are significant price differences [May--personal communication]. Many growers also confer with each other to determine the fair market price of the varieties they intend to purchase [Yerxa--personal communication]. They also are frequently able to negotiate lower seed prices for desirable varieties by purchasing them several months in advance. The usual practice is to deduct 10 percent of the seed price if growers prepay several months early. Some growers prefer to pay for their seed in December to reduce their tax liability for the current fiscal year. Other growers purchase their seed early to be assured of obtaining a desirable variety [Hirahara--personal communication].

IV.5.6. Role of Harvest Schedule in Grower Variety Selections:

The first processing tomatoes in California are harvested in the southern desert regions of California in late June. The harvest gradually moves north to Yolo county

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[47] For example, suppose that a grower has to choose between two varieties. Variety A costs $195 more than variety B but yields an additional ten tons per acre. If the grower uses only half as much seed of variety A than variety B the seed will cost him an additional $82.50 per acre. However, if each ton sells for $50 and yield is increased by ten tons per acre, variety A will increase his gross revenues per acre by $500 and his net returns per acre by $417.50 [Pruett--personal communication].

and ends during the early part of October.[48] Ideally, growers would like to harvest tomatoes during each week of the harvest season since it maximizes the use of their harvesters [Fabbri--personal communication]. However, the grower/processor contract specifies the time frame during which each grower's tomatoes are to be harvested [Miyao--personal communication].[49] The harvest schedule thus affects the selection of varieties since they must mature at different times to enable growers to supply the contracted tonnage. For example, if a grower is slated to harvest at the end of July, he will plant early maturing varieties. On the other hand, if he is slated to harvest during the peak of the harvesting season, when processing plants are running at capacity, he may plant a variety like BOS 3155 to take advantage of its excellent field holding.

IV.5.7. Role of Risk Reduction in Grower Variety Selections:

There are three common ways growers reduce risk via variety selection. First, they devote only a small portion of their acreage to new varieties to observe how well they perform before committing a significant portion of their acreage to the variety [Merwin--personal communication]. Second, they commit only part of their acreage

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[48] Tomatoes are first harvested in the south because the region is the first to attain a sufficient number of degree days. However, Colusa county which is in the far northern end of the California growing area, starts harvesting in the early part of July due to a micro-climate associated with warm coastal air [Hirahara--personal communication]. In contrast, growers in the Salinas Valley, which is much further south, start harvesting around the twenty-fifth of August due to prevailing cool weather patterns [Vosti--personal communication].

[49] Processors contract on a weekly basis to make certain their plants run at capacity. During the week the loads have been contracted to be delivered, the processor has the option of either taking the loads or releasing them. If they are released, the grower has to find another processor who is willing to take them. During the past several years, some of the smaller and older processors like Gangi have purchased much of the excess tomatoes [May--personal communication].

to early and/or late maturing varieties since there is an increased risk of crop damage associated with heavy rains and cool weather [Angell--personal communication]. Third, they attempt to select varieties that are able to tolerate environmental stress such as high heat or water shortages.

Although many of the costs growers face are similar across the state, such as the cost of chemicals and labor, there are a number of costs that differ significantly among growers. For example, the cost of water varies tremendously from one region of the state to the next. In the Delta region, water is practically free since it comes right to the edge of the growers' fields. In the south, where desert conditions prevail, growers pay a significant amount per acre foot of water [Merwin--personal communication].[50] Thus, drought tolerant varieties are in demand in these areas. Land without water is worth only $200 per acre, whereas land in the Salinas Valley is very expensive since water is easily accessible which permits the production of many high value crops [Pruett--personal communication].[51]

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[50] The cost of water in the California processing tomato growing regions ranges between $0 and $150 per acre foot [Robertson--personal communication].

[51] In the Salinas Valley, the cost of renting land ranges between $800 and $2000 per acre [Vosti--personal communication]. There is tremendous demand for land in the Salinas Valley because it can be used to grow two to three high value vegetable crops each year [Yerxa--personal communication].

CHAPTER V

METHODOLOGY

One purpose of Chapter V is to describe the theoretical framework which was used to estimate the average profits of the top thirty processing tomato varieties inspected between 1991 and 1995. A second purpose is to describe the theoretical framework used to estimate the implicit prices of important processing characteristics. The first part of the chapter treats the methodology developed to estimate the average profits of the top varieties. The second part of the chapter treats the basic theory behind hedonic price estimation. The section also addresses how the technique is applied to differentiated factors of production, and includes examples of how other studies have used hedonic techniques to estimate the implicit prices of agricultural inputs.

V.1. Methodology Used to Estimate Grower Profits:

A number of steps were required to estimate the average grower profits. The profits were estimated for the top thirty varieties inspected by PTAB over the past five years in Yolo, San Joaquin and Fresno counties and for the entire state of California. Most of the steps involved estimating the average revenues per load for each of the top tomato varieties which were then converted into average revenues per acre. The remaining steps involved estimating the average cost of production per acre

for each of the top varieties. Costs were then subtracted from revenues to obtain the estimated profits per acre.

V.1.1. Estimation of Average Revenue per Acre:

Eight steps were needed to estimate the average revenues per acre for the top thirty varieties. The first step involved estimating the average percentage of each variety's production processors deducted from paid tonnage due to quality deficiencies. Deductions were taken if the percentages of worm damage (W), mold (R), green tomatoes (G), material other than tomatoes--referred to as MOT (V), and limited-use (U) exceeded levels specified in grower-processor contracts. If the quality defects exceeded the specified levels, the processors multiplied either the entire percentage or the percentage above the infraction level by one or greater and deducted the resulting number from the gross weight. Since the multiplying factors and the base levels differed somewhat among processors, a weighted average of deductions was calculated by summing each processor's share of total weekly processing capacity. This was then multiplied by the penalties assessed by each processor. The method used to calculate deductions can be expressed as follows:

$$D_{ij}^{t}=W_{ij}^{t}M_{w}^{t}+R_{ij}^{t}M_{r}^{t}+G_{ij}^{t}M_{g}^{t}+V_{ij}^{t}M_{v}^{t}+U_{ij}^{t}M_{u}^{t} \qquad (1)$$

where D_{ij}^{t} represents the total deductions suffered by variety **i** in region **j** during year **t**. The deduction multiplying factor (M_{α}^{t}) was calculated as follows:

$$M_a^t = \sum m_k^t H_k^t \quad (2)$$

where $\mathbf{m_k^t}$ represents the multiplying factor for processor **k** during year **t** and $\mathbf{H_k^t}$ represents the share of weekly processing capacity for processor **k** during year **t**. The total deductions were then used to calculate the net paid weight per variety by multiplying the average load weight during year **t** for all varieties by each variety's total deductions. This is expressed as:

$$F^t D_{ij}^t = N_{ij}^t \quad (3)$$

where $\mathbf{F^t}$ represents the average load weight during year t, and $\mathbf{N_{ij}^t}$ represents the net paid weight for variety **i** in region **j** during year **t**. The third step involved estimating the average base price growers received from processors each year between 1991 and-1995. This is expressed as:

$$B^t = \sum b_k^t H_k^t \quad (4)$$

where $\mathbf{B^t}$ represents the average base price growers received from processors during year **t**, and $\mathbf{b_k^t}$ represents the base price for processor **k** during year **t**.

Each variety also earned incentives which were added to the base price. During the years in question, processors offered growers incentives for early season production (E), late season production (L), low MOT (V), low limited-use (U), superior color (C), and high soluble solids (S). Very few of the processors offered

early season incentives. In contrast, nearly all of the processors offered substantial late season incentives. Although incentives were offered by most of the processors for low MOT and limited-use in the majority of cases, the incentives were very low. Finally, although processors claim that high soluble solids are very important to them in reducing processing costs, on average they offered very small incentives. The incentives were usually substantial for soluble solids levels 6 percent or greater--which is rarely attained by growers. Processors may have reduced the soluble solids incentives since soluble solids have increased across the board in recent years for most of the top varieties. The method used to estimate total incentives per variety can be expressed as follows:

$$I_{ij}^{t}=IE_{ij}^{t}+IL_{ij}^{t}+IV_{ij}^{t}+IU_{ij}^{t}+IC_{ij}^{t}+IS_{ij}^{t} \qquad (5)$$

where IE_{ij}^{t}, IL_{ij}^{t}, IV_{ij}^{t}, IU_{ij}^{t}, IC_{ij}^{t} and IS_{ij}^{t} represent the incentives offered for early season production, late season production, low MOT, low limited-use, superior color, and high soluble solids respectively while I_{ij}^{t} represents total incentives for variety **i** in region **j** during year **t**. The sum of the base price and the incentives earned per variety represents the total amount paid per ton for each of the top varieties. This can be expressed as:

$$B^{t}+I_{ij}^{t}=A_{ij}^{t} \qquad (6)$$

where A_{ij}^{t} represents the average price processors paid growers for variety **i** in region **j** during year **t**. This result was then used to calculate the total revenues per load which can be expressed as:

$$TR_{ij}^{t}=N_{ij}^{t}A_{ij}^{t} \tag{7}$$

where TR_{ij}^{t} represents the total revenue for variety **i** in region **j** during time period **t**. The total revenue per variety was then divided by the total average load weight before deductions were taken as a preliminary step to calculate the revenue per acre. This can be expressed as:

$$UR_{ij}^{t}=\frac{TR_{ij}^{t}}{F^{t}} \tag{8}$$

where UR_{ij}^{t} represents the total revenue per ton before adjusting for deductions. Finally in step eight, the average revenue per acre was calculated by multiplying the estimated yield per acre for each variety by the total unadjusted revenue per ton. This can be expressed as:

$$AR_{ij}^{t}=UR_{ij}^{t}Y_{ij}^{t} \tag{9}$$

where Y_{ij}^{t} represents the estimated yield (tons) per acre for variety **i** in region **j** during year **t** and AR_{ij}^{t} represents the average revenue per acre for variety **i** in region **j** during year **t**.

V.1.2. Estimation of Average Cost per Acre:

Costs were much easier to estimate than revenues since it was assumed that only three cost components vary depending on the variety selected: harvest costs per acre, seed costs per acre and the average rent paid per acre. The estimated variable costs were then added to the estimated base costs to obtain an estimate of the total costs per acre. As a result, only four steps were needed to estimate costs. In step one, the harvest costs per acre were estimated by multiplying the average yield per acre by the average cost of harvesting each ton. This can be expressed as:

$$HC_{ij}^{t} = Y_{ij}^{t} K^{t} \qquad (10)$$

where K_t equals the harvest cost per ton during year **t** and HC_{ij}^{t} represents the total harvest cost for variety **i** in region **j** during year **t**.

In step two, the cost of seed was calculated for each of the varieties. For hybrid seed, it was assumed that growers plant an average of 60,000 seeds per acre while growers plant an average of 1.2 pounds of open pollinated seed. This can be expressed as:

$$SC_{i}^{t} = Q_{i}^{s} P_{i}^{st} \qquad (11)$$

where Q_i^s represents the quantity of seed of variety **i** used per acre, P_i^{st} represents the price of seed per 100,000 seed unit or per pound for variety **i** during year **t**, and SC_i^t represents the cost of seed per acre for variety **i** during year **t**. In step three, the rental cost of land was calculated and can be expressed as:

$$RC_{ij}^{t}=AR_{ij}^{t}*.15 \quad (12)$$

where RC_{ij}^{t} represents the land rental cost for land planted with variety **i** in region **j** during year **t**. The average revenue per acre was multiplied by .15 to calculate land rental costs since processing tomato crop budgets, and conversations with industry representatives, revealed that growers are commonly charged 15 percent of their gross revenues as the land payment. In the fourth and final step, all the variable costs were added to the estimated base cost to compute the total costs per acre. This can be expressed as:

$$TC_{ij}^{t}=BC^{t}+HC_{ij}^{t}+SC_{i}^{t}+RC_{ij}^{t} \quad (13)$$

where BC^{t} represents the base cost per acre during year **t** and TC_{ij}^{t} represents the total cost per acre for variety **i** in region **j** during year **t**.[1]

The average costs were then subtracted from the estimated revenues to obtain an estimate of average profitability per acre per variety. This can be expressed as:

$$\pi_{ij}^{t}=AR_{ij}^{t}-TC_{ij}^{t} \quad (14)$$

where π_{ij}^{t} represents the profit per acre for variety **i** in region **j** during year **t**.

[1] Base costs were based on annual crop budgets prepared by the California Cooperative Extension Service for Yolo, San Joaquin, and Fresno counties, and on conversations with farm advisors and growers.

V.2. Theoretical Framework For Estimating Implicit Prices:

Over the past several decades, economists have developed methods to estimate the implicit prices of the characteristics that comprise consumer goods such as housing and agricultural commodities. In the case of processing tomatoes, characteristics include such things as disease tolerance, percent soluble solids, and drought tolerance among others. Much of the early theory concerning consumer demand for characteristics was developed by Thiel (1951-52) and Houthakker (1951-52) followed by Lancaster (1966). However, Rosen (1974) is usually credited with developing the formal theory of the implicit prices of characteristics referred to as hedonic prices. The theory has been added to and modified over the past several decades and has been used in numerous applied studies.[2]

The variability in a class of goods can be described by the unique package of characteristics each good contains. The variability results in a range of prices faced by both producers and consumers. Rosen's model describes a competitive equilibrium in a plane of several dimensions on which both buyers and sellers locate. Any location on the plane is represented by the vector of coordinates $\mathbf{z} = (z_1, z_2,\ldots,z_n)$ with z_i measuring the amount of the **ith** characteristic contained in each good. When distinct packages of characteristics are offered a price $\mathbf{p(z)} = \mathbf{p}(z_1, z_2,\ldots,z_n)$ is defined at each point on the plane and guides both consumer and producer locational choices regarding packages of characteristics bought and sold.

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[2] Although Rosen (1974) is given credit for developing the formal hedonic theory Freeman (1974) also developed a similar approach at approximately the same time.

The theory is made operational by making several assumptions. First, it is assumed that a sufficiently large number of differentiated products are available so that the choice among various combinations of **z** is continuous. Second, each z_i is measured so that it may be treated as a good. This implies that firms are only able to alter their products and increase **z** by using additional resources, and thus **p(z)** must be increasing in all of its arguments. Third, in a departure from Lancaster (1966), Rosen assumed that packages of characteristics purchased or sold cannot be untied. Thus, for example, two packages of characteristics cannot be combined to create a single package that is equal to the two packages used separately. The consequences of prohibiting the arbitrage of characteristics is the likelihood that the hedonic price **p(z)** will be non-linear since the differentiated products are sold in separate, highly interrelated markets.[3]

Bearing these assumptions in mind, Rosen (1974) defined a utility function as $U = U(x, z_1, z_2,\ldots,z_n)$ (or $U = U(y - p(z), z_1, z_2,\ldots z_n)$ where **x** is a composite good with a particular value of **z** of which consumers only purchase one unit. Income (**y**) can then be written as: $y = x + p(z)$. Since **p(z)** is nonlinear the budget constraint must also be nonlinear. Maximization of utility subject to the nonlinear budget

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[3] Ladd and Martin (1976) developed an alternative theoretical approach to estimate implicit prices. They assumed that the price of a purchased input equals the sum of the implicit values of the input characteristics. They defined the implicit value to equal the input's marginal yield of a characteristic multiplied by the marginal money value of one unit of the characteristic. To simplify the estimation process, the marginal yield of the characteristics were assumed to be constant. Consequently, the marginal implicit prices were assumed to be constant. Hence, the input is assumed to be linearly related to the quantity and/or quality of the characteristic. This approach fails to consider the non-linearity identified by Rosen (1974), and thus has limited applicability.

constraint requires choosing x and $(z_1, z_2,\ldots,z_n)$ to satisfy the budget constraint and first order conditions:[4]

$$U(x, z_i) + \lambda [y - x - p(z_i)] \quad (15)$$

$$U_x = \partial u/\partial x = \lambda \quad (16)$$

$$U_{z_i} = \partial u/\partial z_i = \lambda \partial p/\partial z_i \quad (17)$$

Thus:

$$p_i = \partial p/\partial z_i = U_{z_i}/U_x \quad (18)$$

where p_i is the marginal implicit price of the good and U_{zi}/U_x is the marginal rate of substitution between z_i and x. The first order conditions require that the marginal rate of substitution between each of the characteristics and the composite good, be equal to the marginal price of the characteristic, $\partial p/\partial z_1$. According to Rosen (1974), consumers reveal their willingness to pay for alternative values of $(z_1, z_2,\ldots,z_n)$ at a given utility level and income by placing bids on distinct packages of characteristics. By inverting the utility function, and holding all but characteristic i constant, an indifference or bid curve is obtained that gives the maximum amount the individual would pay to obtain a particular good as a function of z_1 (Freeman, 1993). Rosen (1974) defined the bid (value) function as:

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[4] Second order conditions are fulfilled on the usual assumptions so long as p(z) is not sufficiently concave.

$$\theta(z_1, \ldots, z_n; u, y) \tag{19}$$

where θ represents the consumer's willingness to pay for alternative values of $(z_1,\ldots,z_n)$ at a given utility and income. The bid function is defined implicitly by:

$$U(y-\theta, z_1, \ldots, z_n) = u \tag{20}$$

By differentiation of (20) we find that the bid function is increasing and concave in the characteristics in z_1, and decreasing in the given level of utility. The first derivative of the bid function can be interpreted as the marginal rate of substitution between z_1 and money, or the implicit marginal valuation a consumer places on z_1 at a given utility and income. Since the marginal valuation also equals the marginal rate of substitution, as discussed earlier, the marginal valuation must equal the marginal (implicit) price (Palmquist, 1991). Through differentiation we obtain:

$$\theta_{z_i} = \frac{U_{z_i}}{U_x} \tag{21}$$

and

$$U_{z_i} U_{z_i} < 0 \tag{22}$$

Since $p(z)$ is the minimum amount the consumer must pay utility is maximized when:

$$\theta(z^*; u^*, y) = p(z^*) \tag{23}$$

and

$$\theta_{z_i}(Z^*; u^*, y) = p_i(z^*), i=1...n \quad (24)$$

where $\mathbf{z}^*$ and $\mathbf{u}^*$ are optimal quantities.

For producers, Rosen (1974) defined **M(z)** as the number of units produced by a firm offering the specification **z**.[5] Total production costs were specified as **C(M,z; ß)** where **ß** is a vector of firm-specific technologies and factor prices. It is derived from minimizing costs subject to constraints that link **M,z** and factors of production.[6] Each plant is assumed to maximize profits which is simply revenues minus costs when **M** and **z** are chosen optimally as shown below:

$$\pi = Mp(z) - C(M, z_1, \ldots, z_n) \quad (25)$$

where unit revenue with specification **z** is given by the implicit price function for characteristics **p(z)**. Firms are competitors although the marginal cost of attributes $\mathbf{p_i(z)}$ is not necessarily constant. This occurs since all firms observe the same price and are unable to affect them by their individual decisions. Hence, the optimal choice of **M** and **z** requires that:

$$p_i(z) = C_{z_i}(M, z_1, \ldots, z_n)/M, i=1...n \quad (26)$$

$$p(z) = C_M(M, z_1, \ldots, z_n) \quad (27)$$

The first order conditions require that a version of the product be chosen such that the marginal price for each characteristic is equal to the marginal cost per unit of

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[5] Rosen limited discussion to the case of non-joint production--in which case each production establishment within the firm specializes in one design and there are no cost spillovers from plant to plant.

[6] Rosen assumed that C is convex with $C(0,z) = 0$ and C_M and $C_{zi} > 0$.

increasing the amount of the characteristic (Equation 26). In addition, the output level must equate product price and the marginal cost of output (Equation 27). The offer prices depend only on the level of profits, and the equilibrium price is determined completely by demand once the level of the characteristic is given (Palmquist, 1991). By inverting a firm's profit function an offer curve for the characteristic in question is revealed. Rosen defined an offer function for the producer as:

$$\phi(z_1, \ldots, z_n; \pi, B) \tag{28}$$

which indicates the unit prices (per model) the firm is willing to accept on various models at constant profit when quantities produced of each model are optimally chosen. A family of production indifference curves is defined by ϕ. The offer function is then found by eliminating M from:

$$\pi = M\phi - C(M, z_1, \ldots, z_n) \tag{29}$$

and

$$C_M(M, z_1, \ldots z_n) = \phi \tag{30}$$

and solving for ϕ in terms of z, profit, and ß. After differentiation we obtain:

$$\phi_{z_i} = C_{z_i}/M \tag{31}$$

which is the reservation supply price for attribute i at constant profit, assuming it is increasing in z_i. Thus, maximum profit and optimum design satisfy:

$$p_i(z^*) = \phi_{z_i}(z^*; \pi^*, B), \; i = 1 \ldots n \tag{32}$$

and

$$p(z^*) = \phi(z^*; \pi^*, B) \tag{33}$$

The equilibrium price schedule is determined by the interaction of the consumers and producers. Buyers and sellers are in equilibrium when the respective bid and offer functions are tangent to each other and with the gradient of the hedonic price function. Therefore, according to Rosen (1974), observations on **p(z)** represent a joint envelope of a family of bid functions and another family of offer functions.

The marginal implicit price of a characteristic can be found by differentiating the hedonic price function with respect to the characteristic in question. This gives the increase in expenditure on **x** that is required to obtain a model with one more unit of z_1, other things being equal. However, since the hedonic price function is generally assumed to be nonlinear, the implicit price of an additional unit of a characteristic depends on the quantity of the characteristic being purchased.

V.2.1. Application to Differentiated Factors of Production:

The model developed by Rosen (1974) is primarily concerned with the equilibrium price relationship between producers and consumers of differentiated consumer products. However, there is also the need to consider the equilibrium price relationships that exist between producers and consumers of intermediate agricultural inputs--such as seeds. In the former case, an equilibrium is found by maximizing the utility of consumers and the profits of suppliers. In the case of intermediate inputs,

an equilibrium is achieved by finding the point of tangency between the hedonic price function, the derived demand for inputs which represents growers willingness to pay for a particular input, and producers willingness to accept payment represented by the maximization of individual profit functions.

Palmquist (1989) developed a framework that extends the Rosen (1974) approach to intermediate factors of production which he suggested could be used to estimate the derived demand for agricultural land. The approach recognizes that the hedonic equation is determined by the interactions of all demanders and suppliers of a particular input. On the demand side, he expressed implicitly the multiple output and multiple input farm production function as:

$$g(x, z, \alpha) = 0 \qquad (34)$$

where x represents the vector of netputs ($x_i > 0$ implies that x_i is an output, whereas $x_i < 0$ implies that x_i is an input) exclusive of the primary input of interest, z is the vector of characteristics of the primary input (seed in the case of processing tomatoes), and α is a vector of farmer characteristics that influence their productive capability.

Although farmers maximize profits, Palmquist (1989) considered variable profits in order to concentrate on the willingness of farmers to pay for a particular input such as seeds.[7] He expressed variable profits as:

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[7] Variable profits were defined as the difference between the value of outputs and the value of inputs excluding the input of interest.

$$\max \pi^{DV} = \sum_{j=1}^{m} p_j x_j \tag{35}$$

subject to:

$$g(x, z, \alpha) = 0$$

and

$$\pi^{DV} \geq 0$$

where π^{DV} is the "variable" profits of the demander of the inputs and $\mathbf{p_j}$ are elements of a vector $\mathbf{p}$ of prices of output and non-seed inputs. The maximization problem (35) can be solved for output supply and non-seed input demand functions:

$$x = x(p, z, \alpha) \tag{36}$$

and substituted back into (35) to yield the variable profit function:

$$\pi^{*DV} = \sum_{j=1}^{m} p_j x_j(p, z, \alpha) \tag{37}$$

If the farmer's seed costs are subtracted from the variable profit function we obtain actual profits, π^{D}.

The equilibrium price schedule is found by equating the bids of growers to use the input and the suppliers' offers to supply the input. A grower's bid for a particular seed type depends on the seed's characteristics, output prices, other input prices, the desired profit level (π), and the farmer's production skills. He defined the bid function as:

$$\theta(z, p, \pi^{D}, \alpha) = \pi^{*DV}(p, z, \alpha) - \pi^{D} \tag{38}$$

The partial derivative of the bid function:

$$\theta_{zi}=\frac{\partial \pi^{DV}}{\partial z_i}\geq 0 \qquad (39)$$

with respect to a characteristic (z_i) is greater than zero since by Diewert (1974) the variable profit function is non-decreasing in fixed factors given certain assumptions about production technology. The partial derivative of Θ with respect to p_j is equal to x_j by the envelope theorem, which is negative for inputs. A grower's bid for an input equals the grower's variable profits minus his desired profit level.

Palmquist (1989) next outlined the decision making process of the input suppliers. The input suppliers seek to maximize their profits by altering the characteristics that are under their control:

$$\max \pi^{s}=R(\dot{z},\acute{z})-C(\dot{z},\acute{z},r,\beta) \qquad (40)$$

$$\pi^{s}\geq 0$$

where π^s represents the profits of the seed company, $R(\dot{z}, \acute{z})$ is the supply price of seeds, $C(\dot{z}, \acute{z}, r, \beta)$ is the cost function, r is a vector of input prices, β a vector of technical parameters, $\dot{z}$ are characteristics exogenous to the input suppliers and $\acute{z}$ are those characteristics within their control. The first order conditions require that the marginal cost of the characteristics under control of the input supplier be equal to the marginal characteristic price in the market.

An offer function $\phi(\dot{z}, \acute{z}, \pi^{S'}, r, \beta)$ represents the prices at which an input supplier is willing to supply inputs to the market. The offer function can be expressed as:

$$\phi(\dot{z}, \acute{z}, \pi^{s'}, r, \beta) = \pi^{s'} + C(\dot{z}, \acute{z}, r, \beta) \quad (41)$$

where $\pi^{s'}$ is the desired profit level. An increase in profits increases the offer price by an equal amount. A seed company maximizes profits by equating the marginal offer prices to the marginal (implicit) prices of characteristics.

V.2.2. Application of Hedonic Functions to Agriculture Inputs:

The hedonic price function has been used to estimate the implicit prices of a number of characteristics associated with agricultural inputs. Wilson (1984), estimated the hedonic prices for malting barley characteristics. Malting barley is used as an input in the brewing process of alcoholic beverages. Protein and plumpness were considered to be the most important identifiable malting characteristics. Due to an inability to account for supply side influences, hedonic prices were estimated separately for four crop years which reduced the year to year variability in the marginal implicit prices. Wilson (1989), also estimated implicit prices to measure the variability in the values of important quality characteristics in the international wheat market.

Espinosa and Goodwin (1991) estimated hedonic prices for Kansas wheat characteristics. Their model considered the impact of different site characteristics on the wheat prices received by farmers. They concluded that the prices received by wheat producers reflects the presence of conventional quality characteristics (such as protein content and the weight per bushel) and the wheat's milling and dough characteristics. Borsen et al. (1984) estimated implicit prices to help explain the bid

prices for rough rice. Several of the characteristics included head weight, test weight and green rice. They also examined the role Federal inspections of rough rice plays in establishing the bid price.

Puttock, Prescott, and Meilke (1990) estimated implicit prices for timber stumpage. The results of their study indicated that volume, species composition, tree size, timber quality and distance to the purchasing mill all affect the lump-sum stumpage prices. Estes (1986), estimated implicit prices for selected green pepper quality attributes. The results of the study indicated that cooler product temperatures and large sized fruit are important physical attributes valued by wholesale buyers. Finally, Jordan et al. (1988), estimated implicit prices for selected quality attributes that affect the prices of fresh tomatoes sold at the retail level. Fruit size, damage, color, firmness, sweetness, acidity and flavor were all found to affect fresh tomato prices.

V.3. Selection of Functional Form:

Since a hedonic price function is a reduced-form equation that reflects the impact of both supply and demand on the implicit price of each attribute, economic theory is usually unable to specify the appropriate function form needed for parameter estimation purposes [Halvorsen and Pollakowski, 1981]. An exception occurs if the product characteristics can be costlessly repackaged. In that case, a non-linear price schedule would permit profitable arbitrage opportunities [Palmquist, 1991].

Although economic theory does not dictate the ideal functional form, most researchers in the past arbitrarily specified either a semi-log or log-linear relationship

between prices and characteristics. Some researchers selected a linear specification solely due to its theoretical interpretation and ease of explanation [Puttock et al., 1990]. With the exception of the log-linear specification, the functional forms mentioned above assume attribute independence. One problem with this approach is that since (according to hedonic theory) an individual's response to different attribute levels is indeterminate, it is necessary to determine the curvature of an attribute's implicit price function and the dependence of each attribute on all other modelled attributes [Milon et al., 1984]. Thus, the linear and semi-log functional forms will frequently result in biased parameter estimates when the model includes more than one independent variable.

In recent years, many researchers have used a Box-Cox functional form in combination with maximum likelihood techniques to estimate hedonic price functions. The approach allows the dependent and independent variable data to choose the appropriate functional relationship. In general, the technique has been found to provide parameter estimates that are more "robust" than the parameter values estimated by arbitrarily selecting the functional form. Box and Cox (1964) introduced the concept of the power transformation which transforms the non-linear variables in a hedonic price function into a linear form which can then be estimated using ordinary least squares (OLS). The power transformation is given by:

$$y^{(\lambda)} = \frac{(y^{\lambda}-1)}{\lambda} \qquad \lambda \neq 0 \tag{42}$$

or

$$y^{(\lambda)} = \ln y \qquad \lambda = 0 \tag{43}$$

After the independent and dependent variables are transformed, the attribute coefficients are estimated as part of a linear function which takes the general form:

$$P^{(\theta)} = \beta_1 + \beta_2 X_2^{(\lambda_1)} + \ldots\ldots\ldots \beta_K X_K^{(\lambda_K)} \qquad (44)$$

where **X** is the level of each attribute, **P** is the price of the good, β_i are the estimated coefficients of the attributes included in the model, θ is the transformation parameter of the dependent variable and $\lambda_1 \ldots \lambda_k$ are the transformation parameters of the independent variables. Under the most flexible circumstances, a separate λ is computed for each independent variable. However, if each variable is assigned a transformation parameter, the computer and programming time are expensive relative to the increased precision of the estimates. It has been found that by assigning one transformation parameter to the dependent variable, and a second albeit identical transformation parameter to each of the independent variables, the loss in economic efficiency is minor [Jordan et al., 1985]. In addition all of the usual alternative flexible forms impose the restriction that $\lambda_i = \lambda_j = \lambda$ [Halvorsen and Pollakowski, 1981].

V.3.1 Advantages and Disadvantages of Box-Cox:

Unlike other functional forms, Box-Cox places no prior restrictions on the attribute relationships. However, it is difficult to interpret the coefficients estimated using Box-Cox since the implicit prices are dependent on the level of other characteristics. Consequently, it is frequently difficult to isolate the role played by one attribute from the roles played by other attribute values [Milon, 1984]. For

example, since the coefficients estimated using Box-Cox do not directly indicate the marginal implicit prices of the attributes they must be transformed as follows:

$$MIP = \beta \left(\frac{\bar{X}^{\lambda-1}}{\bar{P}^{\theta-1}} \right) \qquad (45)$$

where **MIP** stands for the marginal implicit price, β_i is the estimated coefficient for attribute **i**, **X (bar)** and **P (bar)** are the mean values of the independent and dependent variables respectively, and θ and λ are the transformation parameters. The Box-Cox transformation also generally under-estimates the variance-covariance matrix which results in over-inflated t statistic values [Jordan et al., 1988, Spitzer, 1980].

V.3.2. Linear and Quadratic Versions of Box-Cox:

There are two forms of the Box-Cox which have appeared in the literature: quadratic and linear. The quadratic Box-Cox (flexible functional form) can be expressed as:

$$P^{(\theta)} = \beta_0 + \sum_{i=1}^{m} \beta_i X_i^{(\lambda)} + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \gamma_{ij} X_i^{(\lambda)} X_j^{(\lambda)} \qquad (46)$$

while the linear Box-Cox can be expressed as:

$$P^{(\theta)} = \beta_0 + \sum_{i=1}^{m} \beta_i X_i^{(\lambda)} \qquad (47)$$

The major advantages of the quadratic Box-Cox is that it avoids the imposition of theoretically unwarranted restrictions on the underlying demand and supply functions, and it incorporates all other functional forms of interest such as log-linear,

linear and semi-log as special cases [Halvorsen and Pollakowski, 1981].[8] The linear Box-Cox on the other hand has somewhat less flexibility. However, the quadratic Box-Cox requires far more computational time to estimate the coefficients than the linear Box-Cox functional form, and it further complicates the interpretation of the coefficients. In addition, the "second order" functional forms such as the quadratic Box-Cox have had little application to amenity research [Milon, 1984]. Also, the flexibility of the quadratic form it is still somewhat restrictive since it only provides a local approximation to the true function [Palmquist, 1991].

Cropper, Deck and McConnell (1987) conducted Monte Carlo experiments to determine the accuracy of the marginal implicit prices estimated using a number of different functional forms. The functional forms included the Box-Cox linear and quadratic functional forms. After testing six different functional forms, they found that when the hedonic equation was correctly specified, the quadratic and linear Box-Cox functional forms resulted in the closest estimates of the marginal implicit prices. However, when the hedonic equation was misspecified, either due to missing data or because proxy variables were used, the simpler and linear Box-Cox functional forms provided the best results. In contrast, when the quadratic Box-Cox functional form was misspecified, the results were far from the actual values.[9] The authors of the study suggested that since it is seldom possible to correctly specify the hedonic model,

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[8] A flexible functional form such as the quadratic Box-Cox provides a second order approximation to an arbitrary twice differentiable functional form [Halvorsen and Pollakowski, 1981].

[9] They speculated that the quadratic Box-Cox may perform poorly in the case of omitted variables since each marginal implicit price depends on more coefficients than does the linear Box-Cox functional form.

the linear Box-Cox functional form may be the best choice among the six forms tested when the primary goal is to estimate marginal implicit prices.

V.3.3. Estimating Box-Cox Parameters Using M.L.E.:

The Box-Cox functional form is estimated by using maximum likelihood estimation techniques (MLE). The maximum likelihood estimates (MLE) are the values of the Box-Cox transformation parameters (λ) which maximize the probability of obtaining the sample of attribute values (X_i) actually observed [Kennedy, 1984]. In other words, if $f(x_1, x_2,..., x_n ; \Theta)$ is the joint density function for a random sample of size n drawn from a population of a particular attribute with an unknown parameter Θ, the MLE of Θ is the estimated value of Θ that maximizes the joint density function of Θ for fixed $x_1, x_2,...x_n$.[10] If the sample observations are independent, then the joint density function of the sample values $x_1, x_2, ...x_n$ can be written as the likelihood function as follows:

$$L(\Theta) = f(x_1, x_2, ... x_n; \Theta) = \prod_{i=1}^{n} f(x_i; \Theta) \qquad (48)$$

The MLE of Θ is the estimated value of Θ that maximizes the likelihood function [Merrill and Fox, 1970].[11] A necessary condition for the function to be at a maximum is that the partial derivatives of $L(\Theta)$, with respect to each of the unknown parameters, equal zero [Kmenta, 1971].

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[10] Under fairly general conditions the MLE are asymptotically unbiased, efficient and consistent estimates [Kennedy, 1984].

[11] The symbol $\prod$ tells us to multiply $f(x_1; \Theta)$ by $f(x_2; \Theta)$ up to $f(x_n; \Theta)$.

V.3.4. Methods Used to Maximize the Likelihood Function:

The most common method used to maximize the likelihood function in hedonic price models is to use a grid search algorithm such as the non-linear SAS algorithm called PROCNLIN which evaluates alternative values of the transformation parameters until the mean square errors of the estimated coefficients (β_i) of the independent variables are minimized [Estes, 1986]. Jordan et al. (1985) used a grid search to estimate the implicit prices of fresh tomato characteristics. They first used a grid search for values of θ and λ which was set between -2 and 2 with increments of .5. The initial estimates were then used to further narrow the range using an interval of .1. Halvorsen and Pollakowski, 1981] performed a grid search over values of θ and λ between -1 and 2.

V.3.5. Testing for Best Functional Form:

Once the maximum likelihood estimates have been computed, researchers have frequently used likelihood ratio tests to test the null hypothesis that there exists a significant difference between the Box-Cox functional form and various other functional forms such as semi-log and log-linear. For example, Jordan et al. (1988) found that there was no significant difference between the Box-Cox functional form and a linear function. It was thus possible to use conventional OLS to estimate the hedonic model using a linear function which greatly simplified the interpretation of the results. Puttock et al. (1990), who examined the stumpage price of timber in Ontario, found that the Box-Cox functional form was significantly different than both the linear and log forms. Despite this, they re-estimated the model using a log

functional form since they found that it provided numerically similar price forecasts to the unrestricted Box-Cox model.[12]

V.4. Estimating Implicit Prices of Processing Tomato Characteristics:

The hedonic technique was used to estimate stage I implicit prices for processing tomato seed characteristics that are deemed to be the most important by growers and processors. The implicit prices were estimated using a linear Box-Cox functional form. However, various functional forms were tested to obtain the best possible fit for the data. The dependent variable (P_i^t) is the actual prices growers paid for processing tomato variety **i** during year **t** for the years 1992 though 1996.[13] The independent (exogenous) variables used include three that are deemed to be important primarily to processors: viscosity, soluble solids and multi-use potential; three variables that are deemed to be important primarily to growers: vine size, yield potential, and nematode resistance; and four variables that are deemed to be very important to both growers and processors: fruit color, field holding, molds and maturity length.

Implicit prices were estimated each year between 1992 and 1996 at the state level and for several counties. The first set of regressions focus on the implicit prices of characteristics at the state level. The second through fourth sets of regressions

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[12] Under the null hypothesis, twice the difference in the logarithmic likelihood between a null and an alternative hypothesis is distributed as chi-squared with the number of degrees of freedom equal to the difference in the number of transformation parameters [Halvorsen and Pollakowski, 1981].

[13] According to seed dealers, the price charged for seed is fairly uniform between regions. Thus, it was assumed that the price for variety **i** was the same in each region.

focus on the implicit prices of characteristics in Yolo, San Joaquin and Fresno counties. The three counties were selected since they have historically produced a large share of the total state production, and they are differentiated by climate, soil types, diseases and other factors. The estimated coefficients were then compared to observe any significant differences. The estimated model was specified as follows:

$$\begin{aligned} P_i^{t(\theta)} = {} & \beta_1 + \beta_2 COLOR_{ij}^{t-1(\lambda)} + \beta_3 HOLD_{ij}^{t-1(\lambda)} + \beta_4 VIS_i^{(\lambda)} \\ & + \beta_5 SOLIDS_{ij}^{t-1(\lambda)} + \beta_6 MULT_i + \beta_7 VINE_i \\ & + \beta_8 YIELD_{ij}^{t-1(\lambda)} + \beta_9 MOLD_{ij}^{t-1(\lambda)} + \beta_{10} NEMA_i \\ & + \beta_{11} MATURE_i^{(\lambda)} \end{aligned} \tag{49}$$

where:

$COLOR_{ij}^{t-1}$	=	The average value of the agtron color reading estimated during inspection for variety i in region j during year t-1.
$HOLD_{ij}^{t-1}$	=	Limited-use levels for variety i in region j during year t-1 which served as a proxy for field holding.
VIS_i	=	Average juice bostwicks for variety i
$SOLIDS_{ij}^{t-1}$	=	Average soluble solids for variety i in region j during year t-1.
$MULT_i$	=	Multiple use potential of variety i.
$VINE_i$	=	Vine size of variety i.
$YIELD_{ij}^{t-1}$	=	Average yield potential of variety i in region j during year t-1.
$MOLD_{ij}^{t-1}$	=	Average mold level for variety i in region j during year t-1.
$NEMA_i$	=	Discrete variable which indicates whether variety i is nematode resistant.
$MATURE_i$	=	Length of maturity of variety i.

The characteristic values for five of the characteristics (color, field holding, soluble solids, mold level and yield) were lagged one year. In the case of the first four lagged variables, the characteristic values are an average of variety data recorded by PTAB at the county and state levels between 1991 and 1995. In the case of yield, the characteristic values are an average of yield data collected as part of county field trials conducted between 1985 and 1995 by the California Cooperative Extensive Service. The variables were lagged since seed prices are partly a function of how well each variety performed in previous years.[14] Average data were used since growers learn in a "bayesian" sense the likely performance of each variety. Based on their previous experience, growers would be expected to pay more for varieties that have a proven track record, and less for varieties that have been inconsistent and/or inferior.[15] The remaining independent variables (viscosity, maturity length, multi-use, vine size and nematode resistance), were not lagged since they were assumed to remain constant over time.

Seed prices, color, field holding, soluble solids, yield, maturity length, viscosity and mold were initially modified by the Box-Cox power transformation until

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[14] High quality data for mold, limited-use, soluble solids and color were only available between 1991 and 1995. Prior to 1991, PTAB did not collect comprehensive data by variety for each of the quality based characteristics. Thus, the average quality data used to estimate the 1996 implicit prices, were based on PTAB data collected between 1991 and 1995. Lagged yield data were based on data collected between 1985 and 1995. Unlike PTAB, the Cooperative Extension Service has collected comprehensive yield data for many years. Thus, the yield data used to estimate the 1996 implicit prices, were based on field trial data collected between 1985 and 1995.

[15] The implicit prices for each succeeding year were estimated using more data than the preceding years.

the final form of the model was selected.[16] Multiple-use, vine size and nematodes were not transformed since they are categorical variables.

V.5. Sources of Data:

The data needed to estimate profits and the implicit prices of characteristics were collected from a number of different sources. To estimate the average profits of the top varieties, information regarding average weight per load, total deductions and incentives were obtained from annual PTAB summary tables for loads inspected between 1991 and 1995. Incentives and deductions data were also obtained from a list of processor/grower negotiated prices which is published annually by the California Tomato Growers Association. The base prices per ton were estimated using data collected from individual processors regarding weekly capacities and from the processor/grower negotiated price lists.[17] Harvest costs per ton were estimated using information gathered during grower interviews and by using crop budgets prepared by the California Cooperative Extension Service for various counties. Seed prices were obtained from several seed dealers, seed companies and from the results of the mail survey of California tomato growers. Base production costs were estimated using crop budgets for several counties.[18]

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[16] For the final form of the model, only the seed price was transformed by the Box-Cox power function. This is discussed in more detail in Chapter VI.

[17] The base prices were first calculated for each processor. The base prices were then weighted by each processor's share of total weekly capacity. The sum of the weighted shares represents the average base price across all processors.

[18] Annual crop budgets were obtained for Yolo, San Joaquin and Imperial counties for 1992. The crop budgets were then broken down by expense category and compared against each other. Base production costs in each of the other years were calculated by adjusting the 1992 costs by the producer

Actual yields for each of the top varieties were estimated using a combination of data collected from the grower survey, average variety yields obtained from field trials and average county and statewide yields for all varieties inspected between 1991 and 1995.[19] The estimated yields were then confirmed by plant breeders at each of the major seed companies.

To estimate implicit prices of characteristics, data for four of the independent variables were obtained from the annual summaries of variety loads published by the Processing Tomato Advisory Board. Each year the organization publishes a summary of how each of the varieties performed for several key quality traits at the state and county level. Data on the four characteristics include fruit color (comminuted color reading), limited-use, which serves as a proxy for field holding, soluble solids and various molds. Data for the remaining six independent variables were obtained from several different sources. Data on viscosity were obtained from annual variety trials conducted in Yolo, San Joaquin and Fresno counties; and from seed dealers and seed companies. Information on vine size, multi-use potential, nematode resistance and maturity length was obtained from seed dealer variety guides and seed companies. Information on yields was obtained primarily from variety trials and from the results

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price index.

[19] Yields obtained from the survey were compared against the average yields estimated by the field trials conducted between 1985 and 1995. In general, field trial yields tend to be 10 to 20 percent higher than actual yields since farmers make certain that their experimental plots receive extra attention. Yields for each variety were also compared against yields for the same variety in each of the counties and the state to make certain the estimated yields were consistent. Finally, the estimated base yields were deflated to reflect how weather affected yields during each of the target years (1991-95). For example, if the average base yield for Yolo county was estimated to be 40 tons, while the actual average yield for all varieties harvested in Yolo county during 1991 was 36 tons, the base yield was multiplied by the ratio of the actual yield to the base yield. The base yields for each variety were then multiplied by this number and served as the estimated yields during one of the target years.

of the grower survey. In addition, some of the data were obtained from the December and January issues of The California Tomato Grower which is published monthly by the California Tomato Growers Association. Finally, data on seed prices were obtained from seed companies, seed dealers and from the results of the grower survey.

CHAPTER VI

EMPIRICAL RESULTS

The purpose of Chapter VI is to analyze the results obtained when the methodological framework outlined in Chapter V was applied to processing tomato price and characteristic data. The first part of the chapter focuses on the estimated average profitability of the twenty-five varieties with the largest load shares inspected by PTAB between 1991 and 1995. Average profits were estimated for three different regions (Yolo, San Joaquin and Fresno counties) and for the entire state during each of the five years. The second part of the chapter focuses on the estimated implicit prices of important processing tomato characteristics. Although the implicit prices were estimated for the same regions as in the first part of the analysis, the time period analyzed was from 1992 to 1996.

VI.1. Estimated Average Profitability of the Top Varieties:

The average per acre profits of the top twenty-five varieties were estimated for each year between 1991 and 1995. The estimated profits were adjusted by the consumer price index, and were expressed in 1995 dollars. The average annual profits were then averaged over all five years. However, since only a portion of the varieties were included among the top twenty-five load shares during each of the five years, the overall average is sometimes based on five years, and in some cases it is based on only two years. As a result, the annual averages may provide a more

accurate assessment of the true profitability ranking of the individual varieties.[1] In some cases, if a variety only appeared one time among the top twenty-five load shares over the five year period, it was not included in the analysis. In addition, since average profits were calculated for the top twenty-five load shares for each of the five years, a total of thirty different varieties were included in the analysis.[2]

VI.1.1. Average Variety Profitability in California:

The average profitability of SUN 5715 ranked either first or second among the top twenty-five varieties inspected in California each year between 1991 and 1995 (Table 6.1A). Despite this, the variety ranked eleventh in total load share over the five year period (Table 6.1B). There are several possible reasons why this occurred. First, it performed less well than many of the other top varieties in several important characteristic categories. For example, it ranked nineteenth for limited-use, fourteenth for color, twenty-fourth for soluble solids and tenth for viscosity (Table 6.1C). It also only ranked ninth in yield potential despite the high correlation between yield and profitability (Table 6.1D).

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[1] For example, the Campbell variety called Shasta was among the top twenty-five load shares of all processing tomato varieties harvested in California during 1991. However, since Shasta was not among the top twenty-five load shares during the years 1992 to 1994, the average profitability of the variety was not listed in the table during these years. In addition, since some of the varieties were not available at some point between 1991 and 1995 (such as Heinz 9280), their average profitabilities were not included in the table for one or more years.

[2] The varieties that only appeared one time were left off of the list for several reasons. First, they contributed only a very small share of total loads. Second, insufficient data concerning yield existed to estimate their average profits for the year in question. Third, an effort was made to focus attention on the thirty varieties which played the most important role over the five year period.

Table 6.1A. Estimated Average Profitability of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in California Between 1991-95

Variety[a]	Average Profitability for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Dollars per Acre					
CAMPBELL CXD 109 SHASTA	332.00	-----	-----	-----	199.12	265.56 (01)
SUN 5715 (OP)	391.25	223.53	138.25	264.92	271.39	257.87 (02)
PETO NEMA 512	380.45	202.50	104.22	245.46	267.72	240.07 (03)
PETO NEMA 1400	329.86	146.67	-----	-----	-----	238.27 (04)
HEINZ 8893	-----	-----	148.67	305.97	-----	227.32 (05)
CAMPBELL CXD 100 ALTA	331.21	149.64	-----	181.41	-----	220.75 (06)
HEINZ 9280	-----	-----	-----	193.22	227.50	210.36 (07)
FM 9208E, PEELMECH (OP)	338.75	212.83	80.67	175.86	209.04	203.43 (08)
BOS 707 (HYBRID)	-----	-----	-----	194.05	212.11	203.08 (09)
FM APEX 1000 (OP)	318.96	196.99	72.77	189.66	216.84	199.04 (10)
CAMPBELL CXD 152	-----	-----	112.87	221.84	243.30	192.67 (11)
BOS 8033	-----	-----	130.71	251.13	-----	190.92 (12)
ASG XPH 5210 BRIGADE	322.47	147.58	67.40	200.96	206.05	188.89 (13)
HEINZ 2710	327.08	158.29	60.55	205.61	-----	187.88 (14)
HEINZ 3044	-----	187.79	88.79	221.42	239.87	184.47 (15)
SUN 1642 (OP)	315.72	143.21	67.48	184.26	206.81	183.50 (16)
HEINZ 8892	-----	173.81	86.79	221.58	244.11	181.57 (17)
FMX 785 (E0204)	311.31	139.57	56.86	171.00	-----	169.69 (18)
HEINZ 8773	308.32	137.54	59.91	-----	-----	168.59 (19)
FM E6203 (OP)	226.11	173.58	54.34	142.19	174.74	154.19 (20)
PETO SPECTRUM 579	293.47	113.52	29.29	138.00	-----	143.57 (21)
BOS 3155 (HYBRID)	282.05	108.56	16.26	136.47	169.50	142.57 (22)
RNK 12 GS	290.97	92.89	-3.39	-----	-----	126.82 (23)
PETO 111B (OP)	240.17	75.66	-2.81	117.90	130.87	112.36 (24)
RNK NVH 4762 LA ROSSA	222.39	52.31	-24.64	94.78	109.88	90.94 (25)
PETO NEMA 1401	217.51	65.29	-13.53	-----	-----	89.76 (26)
H 282	-----	-----	-----	52.78	81.54	67.16 (27)
PETO NEMA 1435 (PSX 3594)	-----	59.60	-2.11	85.72	100.85	61.02 (28)
PETO NEMA 1200	207.43	14.33	-63.42	20.61	64.44	48.68 (29)
HM 3075 DIEGO (OP)	55.55	-77.22	-132.39	-----	-----	-51.35 (30)
Average[c]	286.70	132.97	48.72	176.47	199.83	168.94

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Profitability ranks among the 30 varieties are placed in parentheses.

[c] Average profit of the top 25 varieties weighted by the respective load shares.

Table 6.1B. Load Shares of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in California Between 1991-95

Variety[a]	Load Shares for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Percent Share					
CAMPBELL CXD 109 SHASTA	0.95	0.29	0.21	0.70	1.47	0.72 (27)
SUN 5715 (OP)	3.12	2.98	2.52	1.66	0.95	2.25 (11)
PETO NEMA 512	5.43	5.36	5.27	5.23	2.87	4.83 (04)
PETO NEMA 1400	1.41	1.83	0.68	0.41	0.35	0.94 (23)
HEINZ 8893	0.05	0.03	1.37	1.63	0.08	0.63 (30)
CAMPBELL CXD 100 ALTA	3.81	2.27	0.59	0.89	0.37	1.59 (17)
HEINZ 9280	0.00	0.01	0.03	1.45	3.74	1.05 (20)
FM 9208E, PEELMECH (OP)	4.72	4.92	3.05	2.61	1.37	3.33 (07)
BOS 707 (HYBRID)	0.12	0.05	0.72	0.81	0.71	0.63 (29)
FM APEX 1000 (OP)	4.73	4.41	3.68	2.95	1.01	3.36 (06)
CAMPBELL CXD 152	0.00	0.05	1.17	2.00	1.52	0.95 (22)
BOS 8033	0.00	0.11	1.32	1.33	0.62	0.68 (28)
ASG XPH 5210 BRIGADE	10.87	12.68	12.14	11.18	6.15	10.60 (02)
HEINZ 2710	2.98	2.60	1.60	1.44	0.65	1.85 (14)
HEINZ 3044	0.70	1.96	3.88	3.50	5.40	3.09 (08)
SUN 1642 (OP)	1.89	1.48	1.79	1.05	0.77	1.40 (18)
HEINZ 8892	0.10	1.52	2.19	7.49	17.47	5.75 (03)
FMX 785 (E0204)	5.22	2.94	1.46	1.02	0.28	2.66 (10)
HEINZ 8773	1.09	1.17	1.00	0.77	0.00	0.81 (25)
FM E6203 (OP)	7.70	3.99	3.83	1.84	0.82	3.64 (05)
PETO SPECTRUM 579	1.97	1.67	1.25	0.81	0.10	1.16 (19)
BOS 3155 (HYBRID)	3.12	9.75	15.92	20.86	22.99	14.53 (01)
RNK 12 GS	1.53	1.28	0.98	0.30	0.27	0.87 (24)
PETO 111B (OP)	1.55	2.07	2.55	1.84	1.08	1.82 (15)
RNK NVH 4762 LA ROSSA	2.71	3.91	2.92	2.77	2.48	2.96 (09)
PETO NEMA 1401	3.17	2.78	2.38	0.69	0.29	1.86 (13)
H 282	0.17	0.58	0.81	0.90	0.72	0.80 (26)
PETO NEMA 1435 (PSX 3594)	0.64	1.39	1.03	1.33	0.88	1.05 (21)
PETO NEMA 1200	3.13	1.88	2.00	0.89	0.82	1.74 (16)
HM 3075 DIEGO (OP)	4.36	3.59	1.55	0.14	0.01	1.93 (12)

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Load share ranks among the 30 varieties are placed in parentheses.

Table 6.1C. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in California Between 1991-95

	Level and Rank of Selected Characteristics					
	Mold		Limited Use		Color	
Variety[a]	Percent	Rank	Percent	Rank	Reading	Rank
CAMPBELL CXD 109 SHASTA	1.18	15	2.86	14	27.40	30
SUN 5715 (OP)	.88	5	3.14	19	23.74	14
PETO NEMA 512	1.58	25	2.00	8	23.22	6
PETO NEMA 1400	.92	6	5.18	29	25.88	25
HEINZ 8893	1.60	26	1.90	7	23.48	9
CAMPBELL CXD 100 ALTA	1.26	18	4.56	28	25.52	23
HEINZ 9280	.68	4	1.10	1	23.88	17
FM 9208E, PEELMECH (OP)	.94	7	3.50	25	23.88	18
BOS 707 (HYBRID)	1.20	16	3.12	18	23.48	10
FM APEX 1000 (OP)	1.38	20	2.14	9	24.70	20
CAMPBELL CXD 152	1.03	9	3.68	27	25.93	26
BOS 8033	.48	1	1.80	6	23.32	7
ASG XPH 5210 BRIGADE	1.22	17	2.90	15	24.24	19
HEINZ 2710	1.26	19	2.64	13	22.34	1
HEINZ 3044	1.02	8	1.48	2	22.78	4
SUN 1642 (OP)	1.14	14	3.16	21	23.40	8
HEINZ 8892	1.12	13	1.68	5	22.34	2
FMX 785 (E0204)	1.42	21	3.48	24	27.02	29
HEINZ 8773	.56	2	1.72	4	25.58	24
FM E6203 (OP)	1.04	10	3.40	23	23.78	15
PETO SPECTRUM 579	2.18	30	2.62	12	24.82	21
BOS 3155 (HYBRID)	1.46	23	1.66	3	23.60	12
RNK 12 GS	1.06	11	5.88	30	26.72	28
PETO 111B (OP)	2.12	29	3.02	17	22.62	3
RNK NVH 4762 LA ROSSA	.88	6	2.54	11	23.60	13
PETO NEMA 1401	1.44	22	3.38	22	23.56	11
H 282	1.72	28	2.94	16	23.00	5
PETO NEMA 1435 (PSX 3594)	1.50	24	3.52	26	23.86	16
PETO NEMA 1200	.64	3	3.14	20	25.42	22
HM 3075 DIEGO (OP)	1.68	27	2.34	10	26.32	27
Average	1.22		2.88		24.31	

[a] Variety names followed by (OP) are open pollinated varieties.

Table 6.1D. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in California Between 1991-95

	Level and Rank of Selected Characteristics					
	Soluble Solids		Yield per Acre		Viscosity	
Variety[a]	Percent	Rank	Tons	Rank	Reading	Rank
CAMPBELL CXD 109 SHASTA	5.45	5	35.98	2	20.48	25
SUN 5715 (OP)	4.97	24	34.84	9	15.00	10
PETO NEMA 512	5.01	23	36.16	3	15.34	11
PETO NEMA 1400	5.50	3	34.21	14	18.40	23
HEINZ 8893	4.96	26	37.65	1	13.95	4
CAMPBELL CXD 100 ALTA	5.30	10	34.27	12	14.82	6
HEINZ 9280	4.87	27	34.34	10	14.90	8
FM 9208E, PEELMECH (OP)	5.06	21	32.17	22	16.34	13
BOS 707 (HYBRID)	5.23	15	35.00	6	-----	-----
FM APEX 1000 (OP)	5.32	9	32.60	20	-----	-----
CAMPBELL CXD 152	5.49	4	35.14	8	18.06	22
BOS 8033	4.87	28	35.82	4	16.50	14
ASG XPH 5210 BRIGADE	5.20	17	34.33	13	16.73	16
HEINZ 2710	5.03	22	34.52	11	12.95	2
HEINZ 3044	4.85	29	34.87	7	16.62	15
SUN 1642 (OP)	4.96	25	32.59	21	17.36	19
HEINZ 8892	5.11	20	35.23	5	13.82	3
FMX 785 (E0204)	5.53	2	33.88	15	18.55	24
HEINZ 8773	4.66	30	33.49	17	17.15	18
FM E6203 (OP)	5.17	18	30.54	28	14.90	9
PETO SPECTRUM 579	5.29	11	33.68	16	14.88	7
BOS 3155 (HYBRID)	5.44	6	33.01	18	15.78	12
RNK 12 GS	5.22	16	32.72	19	-----	-----
PETO 111B (OP)	5.41	7	30.66	27	12.38	1
RNK NVH 4762 LA ROSSA	5.12	19	31.86	24	16.74	17
PETO NEMA 1401	5.29	12	31.50	25	17.55	20
H 282	5.25	14	31.43	26	14.60	5
PETO NEMA 1435 (PSX 3594)	5.56	1	32.07	23	17.61	21
PETO NEMA 1200	5.27	13	29.71	29	20.74	26
HM 3075 DIEGO (OP)	5.40	8	26.00	30	-----	-----
Average	5.19		33.39		16.24	

[a] Variety names followed by (OP) are open pollinated varieties.

Second, few loads of the variety were harvested since it is a "niche" variety which is planted in areas where high temperatures frequently inhibit more temperature sensitive varieties from setting fruit. Third, it is primarily used to produce paste, and it has limited use for peeling and dicing. Varieties which peel and dice well have become increasingly important due to the growing popularity of salsa and other tomato products [Angell--personal communication]. Fourth, the load share of the variety gradually declined from 3.12 percent to only .95 percent between 1991 and 1995. This partly occurred because processors and growers have shifted away from planting open pollinated varieties such as SUN 5715, to much more expensive hybrid varieties.[3]

In some cases, growers mistakenly reject a variety because they lack sufficient information to make fully informed decisions. For example, the average profitability of a variety sold by Campbell Seeds called CXD 152 was ranked between fourth and fifth among the twenty-five California varieties with the largest load shares. However, the load share of CXD 152 was ranked twenty-second. Despite the variety's high profit potential, growers prefer not to plant it since they claim it quickly develops mold and has poor field holding. They are only willing to grow CXD 152 if they also are allowed to grow other more dependable varieties. A review of PTAB statistics revealed that the variety ranked nineth for total mold and twenty-seventh for limited-use which served as a proxy for field holding. However, the

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[3] One of the chief reasons why SUN 5715, which is produced by Sunseeds, is so profitable is because the seed costs only $30 to $40 dollars per hundred thousand seeds. In comparison, a typical hybrid variety costs on average approximately $200. If SUN 5715 seed cost as much as hybrid seed, the average profitability of the variety would have fallen below the top fifteen most profitable varieties included among the top twenty-five load shares.

average mold level according to PTAB statistics was below the statewide average, and was significantly lower than many of the other top twenty-five varieties. In addition, although limited-use is relatively high, it falls below the threshold level specified in the grower/processor contracts. Above the threshold level, processors are allowed to deduct the percentage of limited-use from grower payments.[4] At the same time, the soluble solids for CXD 152 ranked fourth, which in many instances would have been rewarded with processor incentive payments. Processors also may have rejected the variety since it only ranked twenty-sixth for color and twenty-second for viscosity.

In some cases, growers and processors adopt varieties which perform relatively poorly during PTAB inspections and which have only average profitability. Brigade (ASG XPH 5210), which is produced by Asgrow, had the highest load shares among all of the varieties inspected by PTAB during 1991 and 1992. Growers and processors like Brigade because of its agronomic flexibility and multi-use potential. However, it performs less than admirably in several PTAB characteristic categories. Processors may have started to switch to other varieties since Brigade ranked nineteenth for color, seventeenth for soluble solids, and sixteenth for viscosity. Growers also gradually became somewhat disenchanted with the variety since it ranked seventeenth for mold, fifteenth for limited-use and thirteenth for yield. They also may have come to realize that the profit potential is not as high as alternative varieties. In addition, other varieties with equal or superior multi-use potential and other agronomic characteristics were subsequently developed. This gave growers and

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[4] Virtually all of the processors only start to take deductions once the limited use level exceeds 5 percent.

processors a wider range of alternative varieties to choose from. As a result, by 1995 Brigade had slipped to the third highest load share.

One of the two varieties which displaced Brigade from the top of the load share list was BOS 3155. Between 1993 and 1995 BOS 3155 was the number one variety with load shares ranging between 15.92 and 22.99 percent. The variety rose to the top of the load share list although its average profitability ranked between fourteenth and seventeenth and its yield potential was ranked eighteenth. There are a number of reasons why BOS 3155 was able to capture and maintain its dominant market position. First, processors like BOS 3155 because the stem is easy to remove during processing, which is important for whole peel and diced products. Second, it has higher than average soluble solids, excellent color and can be used for several different cannery products [Nichols--personal communication]. Third, growers favor BOS 3155 since it has excellent field holding and is mold resistant. They are able to leave the crop in the field for an extended period of time and suffer only minimal losses due to higher limited-use [Storz--personal communication]. Fourth, growers like the variety since they are able to plant it on poor soil and still obtain reasonably high yields [Timothy--personal communication].

Although BOS 3155 is an excellent variety, there are a number of reasons why it has not completely taken over the seed market. First, it has a large indeterminate vine which is not well suited to fields which are planted in double rows [Robertson--personal communication]. Second, it lacks nematode and Bacterial speck resistance which means that it frequently cannot be planted in areas which are affected by these pathogens. Third, it has a long maturation cycle which is not well suited to areas

such as the Delta region, which experiences cool weather and dew formation late in the season. It also is not ideally suited for Fresno county where a high percentage of the crop is harvested early [Merwin, Hirahara--personal communications]. Fourth, the viscosity is not as high as the viscosity of Brigade and other varieties. Fifth, some varieties are better suited for peeled and diced tomato production [Rivara--personal communication]. Sixth, in past years the demand for the variety has outstripped supply, which has caused growers to select alternative varieties [Hirahara--personal communication]. Seventh, the retail price of BOS 3155 is oftentimes 10 percent higher than the average retail price of other hybrid varieties. Eighth, growers prefer to plant several varieties which mature at different times to increase their harvesting efficiency, and to satisfy their processor capacity constraints. Ninth, many varieties have a greater yield potential than BOS 3155.

Heinz 8892 is the other variety which dislodged Brigade from the top load share position. Between 1992 and 1994 the load share ranking of Heinz 8892 increased from the seventeenth largest to the second largest. This partly occurred because Heinz controls approximately 10 percent of the state's processing tomato capacity, and because Heinz requires their contracted growers to primarily use in-house varieties. However, the variety is also popular among other processors since it has excellent color (ranked second), high viscosity (ranked third), a compact vine, sets well and matures evenly [Merwin, Robertson--personal communications]. Some processors with older equipment are unable to use Heinz 8892 because the variety's high viscosity jams their equipment. Non-Heinz growers also like the variety since it has low limited-use and high yields, both of which are ranked fifth among the top

twenty-five varieties inspected by PTAB between 1991 and 1995. As a result of the high yield, Heinz 8892 ranked third for average profitability during 1995.

Some varieties maintain a relatively large load share, despite their low profitability, because they are used for specialty packs. A prime example is RNK NVH 4762 La Rossa which is the dominant pear shaped variety used in California. Between 1991 and 1995, the average profitability ranking of the variety ranged between sixteenth and twenty-first, while the load share ranking ranged between seventh and twelfth. Its performance in the PTAB inspection categories, with the exception of mold (ranked 6th), ranged from poor to average. Despite this, some processors like to use La Rossa since it is well-suited for whole peel production, dicing, wedges and sauces and since some consumers prefer pear shaped varieties. Some growers also claim it produces very high yields and that its color is excellent [The California Tomato Grower, 1995].

V1.1.2. Average Variety Profitability by Region:

In many ways, the profitability, load shares and PTAB inspection results at the regional level mirror the state level results. However, due to different soil and climatic conditions, incidence of disease and nematodes and varying access to information and processing plants, there are notable differences in the composition, load share and profitability of the top twenty-five varieties. The remainder of the section focuses on some of the more notable regional differences.

Yolo County:

Fifteen to twenty years ago, Ferry Morse introduced an OP variety called Apex 1000 which became one of the most popular varieties. It is highly adaptable, has medium viscosity and solids, reasonably high yields, and can be used for almost any kind of cannery product [Storz--personal communication]. One small grower only plants Apex 1000 because the processor he sells to likes to use it for whole peel, it holds well in the field, and it produces high yields on good soil [Vosti--personal communication].

Although the average profitability of Apex 1000 in Yolo county consistently ranked between fourth and nineth, its load share ranked between twelfth and twenty-first (Table 6.2A and Table 6.2B). In addition, its load share fell from slightly over 2 percent during 1991, to just .23 percent during 1995. Processors may have been largely responsible for the decline in the use of Apex 1000 since it has relatively poor color, high mold, and low soluble solids (Table 6.2C and Table 6.2D). Growers also may have opted to use alternative varieties since the regional yield of OP varieties is generally lower than competing hybrid varieties.[5] In addition, it is unable to compensate for soil deficiencies, climatic fluctuations and disease problems to the same extent as hybrid varieties.

In some cases, it takes growers and processors several years before they decide to stop using a particular variety. In Yolo county, an OP variety called HM

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[5] The yields of the five OPs included among the top load shares harvested in Yolo county between 1991 and 1995 were ranked between twenty-first (Apex 1000) and thirtieth (HM 3075 Diego).

Table 6.2A. Estimated Average Profitability of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Yolo County Between 1991-95

Variety[a]	Average Profitability for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Dollars per Acre					
HEINZ 9280	-----	-----	-----	434.27	271.36	352.82 (01)
PETO NEMA 512	515.84	365.27	278.50	375.24	220.35	351.04 (02)
HEINZ 8893	-----	-----	290.08	403.30	-----	346.69 (03)
HEINZ 8892	-----	394.77	298.99	396.43	228.45	329.66 (04)
HEINZ 9175	-----	-----	-----	384.59	231.37	307.98 (05)
FM APEX 1000 (OP)	408.03	281.06	185.94	301.18	-----	294.05 (06)
PETO NEMA 1400	411.01	265.22	197.56	-----	-----	291.26 (07)
FMX 785 (E0204)	435.07	266.97	188.82	254.20	-----	286.27 (08)
FM 9208E PEELMECH (OP)	392.18	-----	180.32	-----	-----	286.25 (09)
CAMPBELL CXD 100 ALTA	407.08	254.98	176.18	247.03	-----	271.32 (10)
CAMPBELL CXD 136	-----	-----	223.76	308.63	-----	266.20 (11)
PETO NEMA 1401	386.60	243.53	148.93	253.44	-----	258.13 (12)
CAMPBELL CXD 109 SHASTA	402.84	212.30	-----	280.76	126.54	255.61 (13)
FM E6203 (OP)	361.17	221.16	166.53	-----	-----	249.62 (14)
HEINZ 3044	-----	289.41	210.71	316.75	156.90	243.44 (15)
CAMPBELL CXD 152	-----	-----	215.38	300.46	176.77	230.87 (16)
HM VEGA (HMX 6835)	-----	-----	166.19	272.52	-----	219.36 (17)
FM 48432 YUBA (OP)	335.19	192.73	129.43	-----	-----	219.12 (18)
ASX XPH 5210 BRIGADE	363.76	225.25	158.17	242.85	101.46	218.30 (19)
CAMPBELL CXD 142	-----	281.28	-----	-----	144.15	212.72 (20)
HEINZ 2710	322.19	189.39	104.01	209.68	-----	206.32 (21)
PETO SPECTRUM 579	319.19	182.73	108.25	196.14	-----	201.58 (22)
BOS 3155 (HYBRID)	344.43	200.40	112.54	205.92	62.28	185.11 (23)
U370, VAN DEN BERGH	-----	-----	-----	243.02	105.81	174.42 (24)
FMX 924	-----	-----	-----	243.08	95.10	169.09 (25)
PETO NEMA 1200	232.68	95.88	52.98	-----	-----	127.18 (26)
PETO NEMA 1435 (PSX 3594)	260.48	125.36	58.10	154.11	1.68	119.95 (27)
PETO SAUSALITO PSX 7090	167.86	50.91	-----	-----	-----	109.39 (28)
RNK NVH 4762 LA ROSSA	186.67	69.45	1.33	91.48	-38.26	62.13 (29)
HM 3075 DIEGO (OP)	118.14	6.05	-40.93	-----	-----	27.75 (30)
Average[c]	351.18	214.24	152.43	259.88	128.51	221.25

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Profitability ranks among the 30 varieties are placed in parentheses.

[c] Average profit of the top 25 varieties weighted by the respective load shares.

Table 6.2B. Load Shares of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Yolo County Between 1991-95

Variety[a]	Load Shares for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Percent Share					
HEINZ 9280	0.00	0.00	0.01	1.83	4.11	2.97 (07)
PETO NEMA 512	6.27	6.41	5.60	5.30	2.13	5.14 (03)
HEINZ 8893	0.15	0.07	2.20	2.48	0.00	0.98 (22)
HEINZ 8892	0.27	2.03	1.70	5.93	14.72	4.93 (04)
HEINZ 9175	0.00	0.02	0.21	0.98	0.87	0.42 (30)
FM APEX 1000 (OP)	2.04	1.55	1.13	1.75	0.23	1.34 (19)
PETO NEMA 1400	3.40	2.66	0.84	0.54	0.13	1.51 (17)
FMX 785 (E0204)	11.82	6.09	3.31	2.20	0.49	4.78 (05)
FM 9208E PEELMECH (OP)	1.05	0.80	0.60	0.10	0.23	0.56 (29)
CAMPBELL CXD 100 ALTA	6.17	2.31	0.63	1.39	0.20	2.14 (11)
CAMPBELL CXD 136	0.13	0.87	1.24	1.20	0.53	0.79 (23)
PETO NEMA 1401	5.61	4.40	2.87	1.24	0.47	2.92 (08)
CAMPBELL CXD 109 SHASTA	3.69	1.28	0.46	1.77	3.32	2.10 (12)
FM E6203 (OP)	1.84	1.32	1.63	0.59	0.14	1.10 (21)
HEINZ 3044	0.35	1.41	5.19	2.56	4.91	2.88 (09)
CAMPBELL CXD 152	0.00	0.09	2.07	3.41	1.71	1.82 (14)
HM VEGA (HMX 6835)	0.02	0.41	2.24	0.84	0.19	0.74 (26)
FM 48432 YUBA (OP)	1.36	1.48	0.94	0.00	0.03	0.76 (25)
ASX XPH 5210 BRIGADE	13.66	20.11	21.00	17.67	8.87	16.26 (02)
CAMPBELL CXD 142	0.12	1.61	0.29	0.33	0.80	0.63 (28)
HEINZ 2710	1.43	2.59	1.17	1.48	0.55	1.44 (18)
PETO SPECTRUM 579	3.54	2.71	0.92	0.92	0.05	1.63 (16)
BOS 3155 (HYBRID)	3.70	11.35	21.94	27.87	30.97	19.17 (01)
U370, VAN DEN BERGH	0.00	0.00	0.00	0.61	3.36	1.99 (13)
FMX 924	0.00	0.08	0.45	0.95	1.08	0.64 (27)
PETO NEMA 1200	1.69	2.68	1.03	0.44	0.28	1.22 (20)
PETO NEMA 1435 (PSX 3594)	2.09	2.62	1.44	1.25	0.81	1.64 (15)
PETO SAUSALITO PSX 7090	2.50	0.88	0.43	0.02	0.00	0.77 (24)
RNK NVH 4762 LA ROSSA	3.47	5.63	4.55	3.12	0.82	3.52 (06)
HM 3075 DIEGO (OP)	6.68	3.56	2.10	0.00	0.00	2.47 (10)

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Load share ranks among the 30 varieties are placed in parentheses.

Table 6.2C. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Yolo County Between 1991-95

	Level and Rank of Selected Characteristics					
	Mold		Limited Use		Color	
Variety[a]	Percent	Rank	Percent	Rank	Reading	Rank
HEINZ 9280	.67	1	1.10	2	24.27	17
PETO NEMA 512	1.40	20	1.44	6	23.44	6
HEINZ 8893	1.36	18	1.24	5	23.92	11
HEINZ 8892	1.20	12	1.10	3	22.28	2
HEINZ 9175	1.55	25	2.58	20	21.45	1
FM APEX 1000 (OP)	1.34	17	1.52	8	25.18	19
PETO NEMA 1400	1.02	6	4.38	30	26.08	27
FMX 785 (E0204)	1.44	22	3.02	26	27.04	29
FM 9208E PEELMECH (OP)	1.16	9	2.54	19	25.60	24
CAMPBELL CXD 100 ALTA	1.50	24	4.00	29	25.64	25
CAMPBELL CXD 136	1.62	27	2.50	18	23.86	10
PETO NEMA 1401	1.28	15	2.70	22	24.02	12
CAMPBELL CXD 109 SHASTA	1.20	11	2.88	23	27.34	30
FM E6203 (OP)	.92	5	2.62	21	24.90	18
HEINZ 3044	.86	4	.90	1	23.02	4
CAMPBELL CXD 152	1.10	8	2.98	25	25.28	20
HM VEGA (HMX 6835)	2.24	30	1.80	13	24.04	13
FM 48432 YUBA (OP)	.76	2	1.54	9	24.22	15
ASX XPH 5210 BRIGADE	1.26	14	2.34	17	24.32	16
CAMPBELL CXD 142	1.58	26	3.22	28	25.70	26
HEINZ 2710	1.02	7	1.64	11	22.70	3
PETO SPECTRUM 579	1.92	28	2.06	14	25.42	22
BOS 3155 (HYBRID)	1.46	23	1.18	4	23.78	9
U370, VAN DEN BERGH	1.95	29	1.60	10	23.20	5
FMX 924	1.22	13	1.50	7	25.33	21
PETO NEMA 1200	.86	3	2.12	15	25.56	23
PETO NEMA 1435 (PSX 3594)	1.36	19	3.18	27	24.06	14
PETO SAUSALITO PSX 7090	1.43	21	2.90	24	23.45	7
RNK NVH 4762 LA ROSSA	1.16	10	1.76	12	23.64	8
HM 3075 DIEGO (OP)	1.28	16	2.28	16	26.53	28
Average	1.30		2.22		24.51	

[a] Variety names followed by (OP) are open pollinated varieties.

Table 6.2D. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Yolo County Between 1991-95

	Level and Rank of Selected Characteristics					
	Soluble Solids		Yield per Acre		Viscosity	
Variety[a]	Percent	Rank	Tons	Rank	Reading	Rank
HEINZ 9280	4.80	28	36.60	1	14.90	6
PETO NEMA 512	4.91	27	35.66	5	15.34	9
HEINZ 8893	4.76	29	36.10	2	13.95	3
HEINZ 8892	5.01	24	35.96	4	13.82	2
HEINZ 9175	5.12	19	36.03	3	15.17	8
FM APEX 1000 (OP)	5.04	23	31.11	21	-----	-----
PETO NEMA 1400	5.47	3	33.08	10	18.40	22
FMX 785 (E0204)	5.46	4	32.79	12	18.55	25
FM 9208E PEELMECH (OP)	5.07	21	30.90	22	16.31	13
CAMPBELL CXD 100 ALTA	5.27	10	32.62	14	14.82	4
CAMPBELL CXD 136	5.14	18	33.21	9	18.45	23
PETO NEMA 1401	5.21	13	32.02	18	17.55	17
CAMPBELL CXD 109 SHASTA	5.44	5	34.27	6	20.48	26
FM E6203 (OP)	5.18	16	29.75	25	14.90	7
HEINZ 3044	4.76	30	33.58	7	16.62	14
CAMPBELL CXD 152	5.49	1	33.05	11	18.06	20
HM VEGA (HMX 6835)	5.17	17	32.67	13	18.10	21
FM 48432 YUBA (OP)	5.27	11	29.52	26	18.00	19
ASX XPH 5210 BRIGADE	5.10	20	32.04	17	16.73	15
CAMPBELL CXD 142	5.26	12	33.22	8	20.50	27
HEINZ 2710	4.92	26	30.85	23	12.95	1
PETO SPECTRUM 579	5.19	15	31.31	19	14.88	5
BOS 3155 (HYBRID)	5.38	6	31.16	20	15.78	11
U370, VAN DEN BERGH	4.99	25	32.52	15	17.20	16
FMX 924	5.34	7	32.46	16	18.50	24
PETO NEMA 1200	5.33	8	28.73	27	20.74	28
PETO NEMA 1435 (PSX 3594)	5.49	2	29.82	24	17.61	18
PETO SAUSALITO PSX 7090	5.21	14	28.52	28	16.26	12
RNK NVH 4762 LA ROSSA	5.07	22	28.38	29	15.47	10
HM 3075 DIEGO (OP)	5.29	9	25.31	30	-----	-----
Average	5.17		32.15		16.79	

[a] Variety names followed by (OP) are open pollinated varieties.

3075 Diego, was the least profitable variety included among the top twenty-five varieties for three consecutive years. Despite this, its load share was the third highest during 1991, and the tenth highest during 1993 when grower profits were actually negative. As a result of the poor performance during 1993, the variety was not planted again in commercial quantities. Since Diego did not perform especially well in any of the PTAB inspection categories, and since its yield was the lowest among all of the top varieties, there must have been other factors, such as the significantly lower seed price, which kept the variety popular for several years. It also may have performed relatively better than competing OP varieties before hybrids were widely adopted.

San Joaquin County:

The most profitable variety included among the top twenty-five load shares in San Joaquin county between 1991 and 1995 was Heinz 8768 (Table 6.3A).[6] Despite its high profitability, its load share ranked between sixth and twelfth (Table 6.3B). On the surface, this is somewhat surprising since Heinz 8768 ranked third for mold and limited-use, fifth for color and viscosity and second for yield. However, its soluble solids only ranked twenty-second and it can only be used for paste. This may have discouraged processors who specialize in whole peel and diced packs from using the variety (Tables 6.3C and 6.3D). Heinz uses 8768 since it needs varieties with

[6] Somewhat surprisingly, Heinz 8768 was not included among the top 25 varieties in the other two primary producing counties (Yolo and Fresno) and at the state level.

Table 6.3A. Estimated Average Profitability of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in San Joaquin County Between 1991-95

Variety[a]	Average Profitability for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Dollars per Acre					
HEINZ 8768	802.66	507.35	286.77	589.35	693.23	575.87 (01)
HUNT 247	-----	-----	310.46	627.26	732.31	556.68 (02)
HEINZ 8893	-----	-----	-----	464.47	557.39	510.93 (03)
HEINZ 9175	-----	-----	-----	468.67	550.63	509.65 (04)
PETO NEMA 512	656.32	369.66	162.51	433.84	537.37	431.94 (05)
FMX 785 (E0204)	573.17	253.83	-----	-----	-----	413.50 (06)
HEINZ 8892	-----	404.41	197.23	473.94	561.53	409.28 (07)
UC82 ALL TYPES (OP)	644.49	358.83	176.33	443.32	-----	405.74 (08)
SUN 5715 (OP)	597.59	328.50	159.23	410.79	507.17	400.66 (09)
FM APEX 1000	527.34	268.71	-----	-----	-----	398.03 (10)
HEINZ 3044	580.10	310.36	101.15	374.15	473.11	367.77 (11)
HEINZ 8773	523.73	273.24	89.36	-----	439.40	331.43 (12)
FM 9208E PEELMECH (OP)	513.72	250.95	87.07	318.41	407.53	315.54 (13)
SUN 1642 (OP)	498.15	255.65	74.22	317.92	388.48	306.88 (14)
PETO NEMA 1401	542.33	246.14	57.80	243.05	428.69	303.60 (15)
PETO NEMA 1400	559.00	259.30	69.58	-----	-----	295.96 (16)
CAMPBELL CXD 152	-----	-----	114.83	328.90	431.28	291.67 (17)
ASG XPH 5210 BRIGADE	493.93	221.22	45.44	273.31	370.91	280.96 (18)
HEINZ 8885 (OP)	-----	-----	-----	227.74	301.61	264.68 (19)
PETO 111B (OP)	470.38	194.32	41.58	243.99	363.31	262.72 (20)
BOS 3155 (HYBRID)	473.70	205.17	12.29	260.38	350.32	260.37 (21)
FM E6203 (OP)	453.32	219.55	67.79	-----	-----	246.89 (22)
HEINZ 2710	448.76	190.33	24.44	-----	-----	221.18 (23)
PETO NEMA 1435 (PSX 3594)	-----	-----	-----	176.21	248.13	212.17 (24)
H 282	417.99	157.36	-31.19	193.66	269.77	201.52 (25)
CAMPBELL CXD 136	-----	266.59	80.83	-----	-----	173.71 (26)
RNK NVH 4762 LA ROSSA	297.30	81.64	-96.53	137.08	223.57	128.61 (27)
PETO NEMA 1200	-----	-----	-59.69	145.38	-----	42.85 (28)
HEINZ 8963	-----	-----	-89.49	137.06	-----	23.79 (29)
HM 3075 DIEGO (OP)	196.36	-8.83	-145.67	-----	-----	13.95 (30)
Average[c]	515.49	263.72	83.08	352.93	460.89	335.22

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Profitability ranks among the 30 varieties are placed in parentheses.

[c] Average profit of the top 25 varieties weighted by the respective load shares.

Table 6.3B. Load Shares of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in San Joaquin County Between 1991-95

Variety[a]	Load Shares for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Percent Share					
HEINZ 8768	3.10	5.30	4.35	4.22	1.93	3.78 (08)
HUNT 247	0.09	0.44	1.18	1.37	0.99	0.81 (25)
HEINZ 8893	0.00	0.16	0.41	1.83	0.80	0.80 (27)
HEINZ 9175	0.00	0.02	0.35	1.08	1.16	0.65 (30)
PETO NEMA 512	4.09	7.47	7.90	6.40	3.65	5.90 (05)
FMX 785 (E0204)	2.48	2.44	0.80	0.58	0.00	1.26 (21)
HEINZ 8892	0.00	1.24	5.75	15.18	29.52	10.34 (01)
UC82 ALL TYPES (OP)	5.54	3.77	4.41	2.16	0.00	3.18 (09)
SUN 5715 (OP)	3.20	7.86	5.55	4.54	1.37	4.50 (07)
FM APEX 1000	2.32	1.80	0.58	0.07	0.00	0.95 (22)
HEINZ 3044	1.38	1.10	1.39	1.29	1.88	1.41 (18)
HEINZ 8773	3.62	3.04	1.03	0.14	0.79	1.72 (16)
FM 9208E PEELMECH (OP)	14.26	9.12	4.93	2.56	1.66	6.51 (04)
SUN 1642 (OP)	3.55	5.47	5.78	4.14	3.84	4.56 (06)
PETO NEMA 1401	4.50	2.93	3.19	1.62	1.16	2.68 (13)
PETO NEMA 1400	1.30	3.48	1.69	0.48	0.00	1.39 (19)
CAMPBELL CXD 152	0.00	0.05	2.85	5.47	2.70	2.77 (12)
ASG XPH 5210 BRIGADE	9.40	12.58	11.44	6.39	4.51	8.86 (03)
HEINZ 8885 (OP)	0.00	0.00	0.34	1.22	0.86	0.81 (26)
PETO 111B (OP)	1.55	1.41	1.98	1.37	0.79	1.42 (17)
BOS 3155 (HYBRID)	3.40	5.10	7.84	15.08	16.80	9.64 (02)
FM E6203 (OP)	9.93	3.04	2.23	0.61	0.02	3.17 (10)
HEINZ 2710	4.34	3.15	1.73	0.43	0.13	1.96 (15)
PETO NEMA 1435 (PSX 3594)	0.00	0.25	0.28	1.51	1.32	0.84 (24)
H 282	1.23	3.24	3.67	3.66	2.47	2.85 (11)
CAMPBELL CXD 136	0.00	1.57	0.95	0.27	0.04	0.71 (29)
RNK NVH 4762 LA ROSSA	1.06	2.65	2.19	2.43	2.23	2.11 (14)
PETO NEMA 1200	0.35	0.34	2.23	1.01	0.37	0.86 (23)
HEINZ 8963	0.00	0.20	2.04	0.75	0.07	0.77 (28)
HM 3075 DIEGO (OP)	2.35	3.35	1.20	0.00	0.00	1.38 (20)

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Load share ranks among the 30 varieties are placed in parentheses.

Table 6.3C. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in San Joaquin County Between 1991-95

	Level and Rank of Selected Characteristics					
	Mold		Limited Use		Color	
Variety[a]	Percent	Rank	Percent	Rank	Reading	Rank
HEINZ 8768	.48	3	1.16	3	22.40	5
HUNT 247	1.40	21	1.80	10	22.74	8
HEINZ 8893	1.48	23	2.03	13	22.15	3
HEINZ 9175	.75	7	2.20	15	20.10	1
PETO NEMA 512	1.30	16	1.76	8	23.24	12
FMX 785 (E0204)	1.55	25	5.10	29	27.15	30
HEINZ 8892	.63	5	1.15	2	21.80	2
UC82 ALL TYPES (OP)	.96	8	2.60	18	25.18	25
SUN 5715 (OP)	.74	6	2.72	19	24.76	24
FM APEX 1000	1.30	17	1.45	6	25.38	27
HEINZ 3044	1.02	9	1.14	1	22.18	4
HEINZ 8773	.30	1	1.20	4	23.00	10
FM 9208E PEELMECH (OP)	1.06	10	3.52	24	24.64	23
SUN 1642 (OP)	1.14	11	3.18	20	24.28	22
PETO NEMA 1401	1.38	20	3.44	21	23.52	14
PETO NEMA 1400	1.55	26	5.60	30	25.30	26
CAMPBELL CXD 152	1.28	14	4.58	26	25.75	29
ASG XPH 5210 BRIGADE	1.40	22	3.44	22	24.10	19
HEINZ 8885 (OP)	1.67	27	2.17	14	23.23	11
PETO 111B (OP)	1.88	28	1.88	11	23.30	13
BOS 3155 (HYBRID)	1.32	18	1.78	9	23.82	17
FM E6203 (OP)	1.18	12	3.48	23	24.10	20
HEINZ 2710	.56	4	1.60	7	22.46	6
PETO NEMA 1435 (PSX 3594)	1.48	24	1.98	12	22.80	9
H 282	1.28	15	2.38	16	22.66	7
CAMPBELL CXD 136	2.23	30	4.10	25	23.53	15
RNK NVH 4762 LA ROSSA	1.34	19	2.52	17	23.96	18
PETO NEMA 1200	1.22	13	4.94	27	24.20	21
HEINZ 8963	.40	2	1.43	5	23.58	16
HM 3075 DIEGO (OP)	2.17	29	5.03	28	25.67	28
Average	1.21		2.71		23.70	

[a] Variety names followed by (OP) are open pollinated varieties.

Table 6.3D. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in San Joaquin County Between 1991-95

	Level and Rank of Selected Characteristics					
	Soluble Solids		Yield per Acre		Viscosity	
Variety[a]	Percent	Rank	Tons	Rank	Reading	Rank
HEINZ 8768	4.95	22	39.31	2	14.39	5
HUNT 247	4.98	21	41.62	1	-----	-----
HEINZ 8893	5.03	19	37.66	3	13.95	4
HEINZ 9175	5.49	5	37.44	5	15.17	10
PETO NEMA 512	4.93	24	36.82	6	15.34	11
FMX 785 (E0204)	5.66	2	32.80	16	18.55	24
HEINZ 8892	5.24	10	37.51	4	13.82	3
UC82 ALL TYPES (OP)	4.83	27	34.06	10	-----	-----
SUN 5715 (OP)	4.73	29	34.06	11	15.00	9
FM APEX 1000	5.05	17	31.12	21	-----	-----
HEINZ 3044	4.84	26	34.67	7	16.62	15
HEINZ 8773	4.86	25	33.41	12	17.15	17
FM 9208E PEELMECH (OP)	5.01	20	31.62	20	16.31	14
SUN 1642 (OP)	4.94	23	32.02	18	17.36	18
PETO NEMA 1401	5.31	8	33.05	14	17.55	19
PETO NEMA 1400	5.74	1	32.81	15	18.40	22
CAMPBELL CXD 152	5.55	4	34.35	9	18.06	21
ASG XPH 5210 BRIGADE	5.21	11	33.07	13	16.73	16
HEINZ 8885 (OP)	4.70	30	29.64	26	-----	-----
PETO 111B (OP)	5.18	12	31.11	22	12.38	1
BOS 3155 (HYBRID)	5.44	6	32.17	17	15.78	13
FM E6203 (OP)	5.13	15	30.45	25	14.90	7
HEINZ 2710	5.07	16	31.85	19	12.95	2
PETO NEMA 1435 (PSX 3594)	5.59	3	31.11	23	17.61	20
H 282	5.25	9	31.11	24	14.60	6
CAMPBELL CXD 136	5.18	13	34.64	8	18.45	23
RNK NVH 4762 LA ROSSA	5.04	18	29.30	28	15.47	12
PETO NEMA 1200	5.32	7	29.41	27	20.47	25
HEINZ 8963	4.80	28	28.70	29	14.93	8
HM 3075 DIEGO (OP)	5.18	14	24.33	30	-----	-----
Average	5.14		33.04		16.10	

[a] Variety names followed by (OP) are open pollinated varieties.

high viscosity to produce catsup. The company is able to compensate for the low soluble solids by adding sugar during the manufacturing process. The market share of Heinz 8768 also may have been lower than expected if Heinz restricted sales of the variety to Heinz growers.[7]

As recently as 1991, an OP variety produced by Ferry Morse called FM E6203, which had been the dominant variety in California for many years, contributed the second largest load share in San Joaquin. However, by 1995 the variety's load share had declined to twenty-fifth. It is a little surprising that its load share rank was so high during 1991 because the variety's average profitability consistently ranked between fourteenth and sixteenth. It performed below average in most of the PTAB inspection categories, with the exception of viscosity (ranked seventh), while yield ranked twenty-fifth. Like Apex 1000, it is highly adaptable and can be used for almost any kind of cannery product. Although some growers indicated they have had more success with FM E6203 than with hybrid varieties, it is gradually being replaced by hybrids since it is no longer on processors' preferred variety lists [Merwin--personal communication]. Other growers indicated that processors have shifted to different varieties since they believe it has inferior processing attributes and is less reliable.

Heinz 3044 is an example of a highly profitable variety which needed five years to firmly establish itself in the market. Although the average profitability consistently ranked between fifth and nineth between 1991 and 1994, the load share

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[7] Although Ag-Seeds Unlimited is the Heinz distributor, it did not mention Heinz 8768 in its 1994 and 1995 Processing Tomato Variety Guides.

ranked between seventeenth and twentieth. The load share shot up to tenth during 1995 which seems to indicate that processors and growers have suddenly concluded that Heinz 3044 is one of the better varieties on the market. The variety is undoubtedly popular among growers due to its superior field holding and high yield (ranked seventh). Processors like Heinz 3044 since it is excellent for whole peeling. It ranked first for limited-use, fourth for color and ninth for mold. However, the soluble solids, like those for Heinz 8768, were close to the bottom of the list (ranked twenty-sixth), while viscosity ranked fifteenth. It also may have had a somewhat lower than expected load share since it is an early maturing variety (110 days) which are frequently associated with lower than average quality.

Fresno County:

In contrast to Yolo county, the average profitability of Apex 1000 in Fresno county between 1991 and 1994 ranked between eighth and eleventh (Table 6.4A), while the load share ranked between first and third (Table 6.4B). Fresno may have been able to delay replacing OP varieties with hybrid varieties somewhat longer than in the northern part of the state since it has fewer nematode and disease problems. In addition, the variety's limited-use ranked sixth while its soluble solids ranked seventh (Tables 6.4C and 6.4D).[8] However, in 1995 Apex 1000's load share plunged from

[8] Limited-use is an especially important characteristic in the southern part of the state since the growers are located somewhat farther from processing plants. Limited-use tends to increase the farther the tomatoes must be transported to processing plants.

Table 6.4A. Estimated Average Profitability of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Fresno County Between 1991-95

Variety[a]	Average Profitability for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	----------Dollars per Acre----------					
SUN 5715 (OP)	328.44	152.80	123.97	242.76	220.47	213.69 (01)
HEINZ 2710	300.80	127.06	74.17	225.79	193.69	184.30 (02)
BOS 8033	-----	-----	110.31	237.97	-----	174.14 (03)
FM 9208E PEELMECH (OP)	331.03	101.43	67.60	177.73	162.12	167.98 (04)
BOS 707 (HYBRID)	-----	-----	94.35	213.31	193.71	167.12 (05)
ASG XPH 5210 BRIGADE	291.37	74.33	83.20	202.26	177.98	165.83 (06)
PETO NEMA 512	273.20	96.42	66.46	203.57	153.08	158.55 (07)
HEINZ 3044	-----	115.50	67.64	217.52	196.69	149.34 (08)
SUN 1642 (OP)	249.67	75.45	63.36	184.28	170.33	148.62 (09)
FM APEX 1000 (OP)	258.26	80.20	56.35	184.85	161.77	148.29 (10)
U370 VAN DEN BERGH	-----	-----	-----	148.92	138.85	143.89 (11)
HEINZ 3302	-----	140.85	129.49	-----	-----	135.17 (12)
FM E6203 (OP)	286.66	64.79	35.88	133.03	132.10	130.49 (13)
BOS 3155 (HYBRID)	245.09	33.39	30.76	154.48	144.87	121.72 (14)
RNK 12 GS	279.02	28.60	18.96	-----	101.85	107.11 (15)
RNK NVH 4762 LA ROSSA	208.40	32.27	21.49	137.90	123.28	104.67 (16)
HM 3075 DIEGO (OP)	16.75	-146.72	-----	-----	-----	-64.99 (17)
RNK NVH 4771 (5-7115)	483.07	189.53	-----	-----	-----	336.30 (18)
HEINZ 1916 (OP)	102.34	-39.53	-----	-----	-----	31.41 (19)
HEINZ 8892	-----	-----	11.25	146.00	121.68	92.98 (20)
HEINZ 9280	-----	-----	-----	82.16	68.28	75.22 (21)
PETO NEMA 1435 (PSX 3594)	-----	-----	11.04	110.17	85.66	68.96 (22)
PETO 111B (OP)	158.80	-3.47	-19.23	108.69	77.49	64.46 (23)
RNK NVH 4780 (9-5168)	-----	-----	-----	33.24	63.60	48.42 (24)
HEINZ 8963	-----	-----	-10.79	94.94	-----	42.08 (25)
HEINZ 8885 (OP)	-----	-----	-19.72	78.96	-----	29.62 (26)
PETO NEMA 1200	157.15	-41.81	-75.92	10.84	19.39	13.93 (27)
PETO NEMA 1401	102.02	-67.08	-60.63	-----	-----	-8.56 (28)
H 282	-----	-----	-69.17	38.74	-----	-15.22 (29)
HEINZ 2695 (OP)	-----	-61.38	-67.82	-----	-----	-64.60 (30)
Average[c]	258.19	63.68	43.09	161.41	137.70	132.81

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Profitability ranks among the 30 varieties are placed in parentheses.

[c] Average profit of the top 25 varieties weighted by the respective load shares.

Table 6.4B. Load Shares of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Fresno County Between 1991-95

Variety[a]	Load Shares for Selected Years					
	1991	1992	1993	1994	1995	Average[b]
	Percent Share					
SUN 5715 (OP)	5.64	4.90	4.83	3.03	2.3	4.14 (08)
HEINZ 2710	2.12	2.57	1.52	1.39	1.00	1.72 (15)
BOS 8033	0.00	0.00	1.65	1.51	0.63	1.26 (17)
FM 9208E PEELMECH (OP)	6.40	9.08	5.08	4.74	2.82	5.62 (04)
BOS 707 (HYBRID)	0.19	0.01	1.54	2.04	1.72	1.10 (19)
ASG XPH 5210 BRIGADE	8.13	6.54	7.28	7.04	3.96	6.59 (03)
PETO NEMA 512	3.29	2.89	4.18	4.41	2.81	3.52 (10)
HEINZ 3044	0.00	1.48	3.64	5.11	7.85	4.52 (07)
SUN 1642 (OP)	4.02	2.59	3.48	2.00	1.30	2.68 (11)
FM APEX 1000 (OP)	10.36	9.58	8.45	5.97	1.78	7.23 (02)
U370 VAN DEN BERGH	0.00	0.00	0.00	0.88	1.00	0.94 (20)
HEINZ 3302	0.71	1.37	0.99	0.38	0.13	0.72 (26)
FM E6203 (OP)	10.27	5.78	5.15	4.11	1.86	5.43 (05)
BOS 3155 (HYBRID)	3.06	9.41	15.75	18.69	19.52	13.29 (01)
RNK 12 GS	3.38	3.65	0.97	0.41	0.76	1.83 (14)
RNK NVH 4762 LA ROSSA	2.96	4.41	3.13	4.34	5.58	4.08 (09)
HM 3075 DIEGO (OP)	2.07	1.70	0.04	0.00	0.03	0.77 (24)
RNK NVH 4771 (5-7115)	1.44	2.75	0.49	0.00	0.00	0.94 (21)
HEINZ 1916 (OP)	1.34	1.41	0.59	0.06	0.04	0.69 (27)
HEINZ 8892	0.01	0.74	1.78	5.52	14.86	4.58 (06)
HEINZ 9280	0.00	0.00	0.02	0.91	3.04	1.32 (16)
PETO NEMA 1435 (PSX 3594)	0.00	0.67	1.39	1.33	1.09	1.12 (18)
PETO 111B (OP)	2.10	2.68	3.43	2.50	1.29	2.40 (13)
RNK NVH 4780 (9-5168)	0.00	0.00	0.09	1.39	0.82	0.77 (25)
HEINZ 8963	0.02	0.28	1.34	1.11	0.36	0.62 (29)
HEINZ 8885 (OP)	0.39	0.78	1.22	1.08	0.00	0.69 (28)
PETO NEMA 1200	4.56	2.27	2.91	1.72	1.76	2.64 (12)
PETO NEMA 1401	1.48	0.98	1.34	0.08	0.02	0.78 (23)
H 282	0.01	0.78	0.96	0.92	0.45	0.62 (30)
HEINZ 2695 (OP)	0.45	1.52	0.95	0.61	0.40	0.79 (22)

[a] Variety names followed by (OP) are open pollinated varieties.

[b] Load share ranks among the 30 varieties are placed in parentheses.

Table 6.4C. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Fresno County Between 1991-95

	Level and Rank of Selected Characteristics					
	Mold		Limited Use		Color	
Variety[a]	Percent	Rank	Percent	Rank	Reading	Rank
SUN 5715 (OP)	.84	13	3.40	18	23.62	20
HEINZ 2710	1.50	28	3.60	21	21.34	1
BOS 8033	.50	3	2.16	3	23.12	15
FM 9208E PEELMECH (OP)	.74	8	3.56	20	23.50	19
BOS 707 (HYBRID)	.88	17	3.84	23	22.74	8
ASG XPH 5210 BRIGADE	.80	9	3.90	24	23.40	18
PETO NEMA 512	1.44	27	2.94	12	22.26	7
HEINZ 3044	.60	5	1.76	1	22.16	4
SUN 1642 (OP)	1.16	20	3.26	16	22.84	9
FM APEX 1000 (OP)	1.36	25	2.34	6	24.54	27
U370 VAN DEN BERGH	1.40	26	4.70	27	22.05	2
HEINZ 3302	.86	15	3.42	19	22.24	5
FM E6203 (OP)	.86	16	3.38	17	23.66	21
BOS 3155 (HYBRID)	1.16	21	2.28	5	22.92	13
RNK 12 GS	.68	7	5.46	30	26.68	30
RNK NVH 4762 LA ROSSA	.80	10	2.98	13	22.84	10
HM 3075 DIEGO (OP)	1.28	23	2.43	8	25.10	28
RNK NVH 4771 (5-7115)	.83	12	2.83	11	24.20	26
HEINZ 1916 (OP)	.60	6	2.20	4	23.98	23
HEINZ 8892	1.22	22	2.52	10	22.06	3
HEINZ 9280	.50	4	1.80	2	22.90	12
PETO NEMA 1435 (PSX 3594)	1.06	19	4.78	28	23.30	17
PETO 111B (OP)	1.72	29	3.16	15	22.24	6
RNK NVH 4780 (9-5168)	.80	11	4.38	25	22.95	14
HEINZ 8963	.44	2	2.36	7	24.04	24
HEINZ 8885 (OP)	.84	14	2.48	9	22.84	11
PETO NEMA 1200	.32	1	2.98	14	25.18	29
PETO NEMA 1401	1.02	18	5.14	29	23.20	16
H 282	2.24	30	4.52	26	23.74	22
HEINZ 2695 (OP)	1.30	24	3.70	22	24.14	25
Average	.99		3.28		23.33	

[a] Variety names followed by (OP) are open pollinated varieties.

Table 6.4D. Average Level and Rank of Selected Characteristics of the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in Fresno County Between 1991-95

	Level and Rank of Selected Characteristics					
	Soluble Solids		Yield per Acre		Viscosity	
Variety[a]	Percent	Rank	Tons	Rank	Reading	Rank
SUN 5715 (OP)	5.02	22	35.84	10	15.00	8
HEINZ 2710	5.11	19	37.63	3	12.95	2
BOS 8033	5.04	21	37.18	4	16.50	15
FM 9208E PEELMECH (OP)	5.11	20	33.05	19	16.31	14
BOS 707 (HYBRID)	5.23	12	37.11	5	-----	-----
ASG XPH 5210 BRIGADE	5.36	8	36.33	8	16.73	17
PETO NEMA 512	5.22	13	36.72	7	15.34	10
HEINZ 3044	4.92	25	36.07	9	16.62	16
SUN 1642 (OP)	4.95	24	34.00	15	17.36	20
FM APEX 1000 (OP)	5.38	7	33.45	17	-----	-----
U370 VAN DEN BERGH	5.21	14	36.76	6	17.20	19
HEINZ 3302	5.14	18	38.51	1	15.00	9
FM E6203 (OP)	5.20	15	31.67	23	14.90	5
BOS 3155 (HYBRID)	5.57	4	34.65	13	15.78	13
RNK 12 GS	5.27	10	33.97	16	-----	-----
RNK NVH 4762 LA ROSSA	5.17	17	34.81	11	15.47	11
HM 3075 DIEGO (OP)	5.58	3	26.63	30	-----	-----
RNK NVH 4771 (5-7115)	5.35	9	37.73	2	16.78	18
HEINZ 1916 (OP)	4.81	29	29.45	28	-----	-----
HEINZ 8892	5.19	16	34.79	12	13.82	3
HEINZ 9280	4.83	28	32.48	22	14.90	6
PETO NEMA 1435 (PSX 3594)	5.63	1	34.03	14	17.61	22
PETO 111B (OP)	5.47	5	31.21	24	12.38	1
RNK NVH 4780 (9-5168)	4.89	27	32.82	20	15.50	12
HEINZ 8963	4.78	30	33.27	18	14.93	7
HEINZ 8885 (OP)	5.00	23	30.37	27	-----	-----
PETO NEMA 1200	5.27	11	30.44	26	20.74	23
PETO NEMA 1401	5.59	2	31.21	25	17.55	21
H 282	5.43	6	32.61	21	14.60	4
HEINZ 2695 (OP)	4.92	26	29.45	29	-----	25
Average	5.19		33.81		15.82	

[a] Variety names followed by (OP) are open pollinated varieties.

third to eleventh. This seems to indicate that the market share of OPs in the southern part of the state is also on the decline.[9]

Between 1991 and 1995, Heinz 2710 consistently ranked between the third and sixth most profitable variety included among the top twenty-five load shares in Fresno county. However, the variety's load share only ranked between twelfth and eighteenth. This occurred although it had the third highest average yield potential. Growers may have opted not to grow the variety since it had relatively low ranks for limited-use (twenty-first) and mold (twenty-eighth). Processors on the other hand, must like its superior color (ranked first) and high viscosity (ranked second), although its soluble solids only ranked nineteenth. As in the case of Heinz 8768, the variety can only be used for paste, which may have discouraged some processors from using the variety.

BOS 707 was ranked between the third and fifth most profitable variety included among the top twenty-five load shares in Fresno county between 1993 and 1995. However, its load share only ranked between twelfth and fifteenth. Although its yield potential was ranked fifth, some growers may prefer not to plant BOS 707 since it has relatively high mold (ranked seventeenth) and high limited-use (ranked twenty-third). On the other hand, most processors may be favorably impressed by the variety since it ranked twelfth for soluble solids and eighth for color. It also can be used for both peeling and paste. However, as in the case of the La Rossa variety

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[9] Ten of the thirty varieties included among Fresno's top twenty-five load shares inspected between 1991 and 1995 were OPs. In contrast, during the same time period, only five of the thirty top varieties in Yolo county were OPs.

(RNK NVH 4762), BOS 707 is pear shaped and is used primarily for specialty packs which limits the number of acres planted with the variety.

VI.1.3. Correlation Between Profits, Yield and Load Share:

Given the above results, it is not surprising to find very little correlation between profitability and load shares among the twenty-five varieties with the largest load shares at the regional and state levels. The correlations ranges between zero and 28 percent (Table 6.5). The results were not improved when the correlations between lagged profits and current year load shares were calculated (Table 6.6).[10] At the same time, the correlations between profitability and yield ranged between 82 and 98 percent at the regional and state levels for the same varieties (Table 6.7). Since the linkage between yield and load shares is tenuous, yield appears to have little impact on growers' variety choices. This is somewhat surprising for several reasons. First, higher yielding varieties are more profitable for the grower. Second, most of the varieties with large load shares are included on processor approved variety lists. Thus, growers generally have the option of selecting from among these the ones with the highest average yields. Third, the results of the California processing tomato grower survey indicated that growers rank yield as their most important varietal trait.

There are several possible reasons why there is little correlation between

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[10] Lagged profits were calculated by taking an average of each variety's profitability for the current year and zero to three preceding years. Profits were only calculated for the top twenty-five varieties during each of the years between 1991 and 1995. For example, profits during 1993 represent an average of each variety's estimated profits for the years 1991 through 1993. Average, rather than current year profits were used to calculate the correlation with load shares, since it was assumed that over time growers learn more about each variety's profit potential.

Table 6.5. Correlation Between Variety Profitability and Load Shares for the 30 Most Commonly Inspected Processing Tomato Varieties Harvested at the State and Regional Levels Between 1991-95

	Correlation Coefficients for Selected Years					
Region	1991	1992	1993	1994	1995	Average
Yolo	.1611	.0057	.0738	.1343	.0577	.0865
San Joaquin	.1120	.0648	.2488	.1481	.1000	.1347
Fresno	.1632	.2309	.2179	.2797	.1676	.2119
State	.0658	.1244	.0026	.0598	.1488	.0803

Table 6.6. Correlation Between Average Lagged Profits and Load Shares for the 30 Most Commonly Inspected Processing Tomato Varieties Harvested in California Between 1991-95

	Correlation Coefficients for Selected Years			
Base Year of Average Profits	1992	1993	1994	1995
1991	.055[a]	.062	.118	.047
1992		.099	.124	.032
1993			.146	.041
1994				.096

[a] For example, the correlation between base year average profits during 1991 and load shares during 1995 was completed in two steps. In step I, the average profits for each of the top thirty varieties between the years 1991 to 1994 was calculated. In step II, the correlation between the 1995 load shares and the average profits estimated in step I was calculated.

Table 6.7. Correlation Between Variety Profitability and Yield for the 30 Most Commonly Inspected Processing Tomato Varieties Harvested Between 1991-95

	Correlation Coefficients for Selected Years					
Region	1991	1992	1993	1994	1995	Average
Yolo	.9140	.9469	.9144	.9615	.9846	.9443
San Joaquin	.9624	.9415	.9556	.9582	.9623	.9560
Fresno	.8473	.8993	.8422	.8290	.8655	.8567
State	.9111	.9007	.8757	.8790	.8627	.8858

profitability and load shares. First, growers are risk averse and prefer to choose varieties which they believe will produce stable yields. Second, if growers attempt to minimize processor deductions, it may discourage them from selecting high yielding varieties.[11] Third, since many varieties are sold on the open market, and since many new varieties are marketed each year, growers may lack sufficient information to make informed variety selections. Fourth, some high yielding varieties are best suited for unique soil and climatic conditions and hence are only grown on a limited number of acres.

V1.2. Implicit Prices of Processing Tomato Characteristics:

The implicit prices of processing tomatoes were estimated using version seven, chapter nineteen of a packaged statistical program called LIMDEP [Greene, 1996]. The program allows the user to select one of four different forms of a Box-Cox regression model. Model 1 only transforms the left side of the equation (dependent variable), Model 2 only transforms the right side of the equation, Model 3 transforms both sides of the model and uses the same lambda value, and Model 4 transforms both sides of the model using different transformation coefficients for both sides of the model.[12] The data were initially analyzed using the first three models. The fourth model was not estimated since the marginal improvement in the results does not justify the computational difficulty [Greene, 1993].

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[11] In almost all cases the higher yield more than compensates for the higher deductions.

[12] The Box-Cox model does not transform categorical variables. In the case of the processing tomato regressions, three of the variables were not transformed for this reason: multiple use (MULT), vine size (VINE) and nematodes (NEMA).

After attempting the first three versions of the LIMDEP model, the decision was made to perform the regressions using the classical regression model.[13] In all three models, the lambda values either equaled or were asymptotically close to 1. When the lambda values equal one, the resulting equation is equivalent to the classical regression model. The results of the LIMDEP models were checked against a SAS macro which was designed to transform the dependent variable (which is equivalent to Model 1). The results of the SAS macro indicated that the estimated lambda values also were asymptotically close to one.[14]

Although the lambda values were extremely close to one when Model 3 was used, a likelihood ratio test was performed to test the hypothesis that the correct functional form was either log linear or linear.[15] The chi-squared critical value with one degree of freedom is equal to 3.84.[16] Since the log-linear value obtained from the likelihood ratio test exceeded the critical value in each of the models, it was rejected at the 5 percent significance level. However, at the 5 percent significance level it was not possible to reject the linear model.

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[13] A key advantage of the classical regression model is that the coefficients can be directly interpreted as the marginal implicit prices.

[14] The SAS macro was written by Michael Friendly, a professor in the math and statistics department at York University, Canada during 1991.

[15] The likelihood ratio test is given by: chi-squared(1) = $-2[ln L(\lambda=1 \text{ or } 0) - ln L(\lambda=MLE)]$.

[16] The degrees of freedom of the chi-squared statistic for the likelihood ratio test equals the reduction in the number of dimensions in the parameter space that results from imposing the restrictions. Since two hypotheses are being tested and the number of restrictions equals 1, the number of degrees of freedom equals one [Greene, 1993].

VI.2.1. Estimated Implicit Prices Using the Classical Regression Model:

Although growers indicated that each of the characteristics included in the model are important for either growers or processors, the characteristics seldom had a significant impact on seed prices. The primary notable exceptions were nematode resistance followed by vine size, soluble solids and field holding. In addition, the adjusted R^2 values were disappointingly low--never exceeding .34. This seems to indicate that there are important factors other than characteristic levels which affect seed prices. Many of the potential factors have already been discussed earlier in this chapter and in other chapters.

Since the statewide data sets were the largest, and therefore perhaps the most reliable, most of the analysis focuses on the California regression results. The estimated coefficients for nematode resistance (NEMA) were significant at the 1 percent level during each of the five years the data were analyzed for California (Table 6.8). The implicit prices ranged between $38 and $53 per hundred-thousand seed unit. Although nematode resistance has been available for some time, many varieties such as BOS 3155 lack the trait. Varieties that lack nematode resistance continue to be sold since nematodes are not found at harmful levels in all regions. Also, they are not found on all farms within affected regions. Thus, growers who desire nematode resistant varieties, must pay a premium to obtain the characteristic. Growers are willing to pay the premium since there are no available pesticides that can control nematodes, and the premium is less than the price growers formerly paid for pesticides which have been subsequently removed from the market.

Table 6.8. Implicit Prices of Selected Characteristics of Processing Tomato Varieties Purchased by California Growers Between 1992-96

	Estimated Coefficients for Selected Years				
Characteristic	1992	1993	1994	1995	1996
Vis	1.28 (.28)[a]	1.55 (.35)	.79 (.27)	2.11 (.46)	-.04 (-.02)
Mature	-1.14 (-.66)	-.53 (-.33)	-.73 (.75)	-.57 (-.58)	.54 (.59)
Color	7.58 (1.56)	7.68 (1.13)	2.34 (.53)	-4.54 (-1.02)	.17 (.04)
Mold	8.02 (.37)	-8.03 (-.36)	-18.04 (-1.23)	.84 (.09)	-2.29 (-.21)
Solids	-27.61 (-.76)	6.87 (.19)	33.84 (1.33)	60.80 (2.32)**	64.88 (2.68)*
Hold	3.62 (.43)	-2.14 (-.29)	-9.96 (-1.79)***	-12.25 (-2.00)**	-14.84 (-2.47)**
Yield	-1.50 (-.76)	-2.42 (-1.32)	-.41 (-.30)	.28 (.22)	-.67 (-.51)
Vine	22.78[b] (2.23)**	18.04 (2.09)**	11.11 (1.70)***	.63 (.10)	-3.84 (-.66)
Nema	57.25 (3.16)*	73.30 (4.18)*	40.98 (3.56)*	38.38 (3.73)*	53.21 (5.41)*
Mult	-4.52 (-.39)	-7.69 (-.78)	-.34 (-.04)	-1.75 (-.26)	-4.09 (-.68)
Constant	179.57 (.63)	17.48 (.07)	28.06 (.14)	13.80 (.07)	-157.45 (-.78)
Adjusted R^2	.13	.18	.11	.11	.23
Lambda	1.0	1.0	1.0	1.0	1.0

[a] The t statistics are placed in parentheses.

[b] A single * indicates that the coefficient is significant at the 1 percent level, two ** indicates it is significant at the 5 percent level, and three *** indicates that the coefficient is significant at the 10 percent level.

Between 1992 and 1994 vine size (VINE) was significant at either the 5 percent or 10 percent level. The implicit price of the characteristic ranged between $11 and $23 per vine size category. If the vine size increased to the next categorical level specified in the data set, the seed price increased by the implicit price of the characteristic. This result is not surprising since in recent years many growers have switched from planting their tomato crops in double rows, to single rows which require somewhat larger vines. However, the premium for large vined varieties has gradually declined as new large vined varieties have been commercialized.

Field holding (HOLD) was significant at either the 5 or 10 percent level between 1994 and 1996. For every .1 percent increase in limited-use (which served as a proxy for field holding), the seed price declined between $10 and $15 per hundred-thousand seed unit. This result is expected for several reasons. First, in recent years growers have become more aware of the importance of field holding since increased production has taxed the ability of processing plants to handle all of the tomatoes ready to be harvested during the peak production weeks. The superior field holding of BOS 3155 is one of the primary reasons why it has been the most widely used variety for the past few years. Second, higher limited-use increases growers' risk and uncertainty because it increases the likelihood they will suffer processor deductions.

Soluble solids (SOLIDS) was the only significant characteristic which is of particular interest to processors. The characteristic was significant at the 5 percent level during 1995 and at the 1 percent level during 1996. The results suggest that for every 1 percent increase in soluble solids, the seed price increased between $60 and

$65. If true, growers may not have earned enough additional profits to cover the premium they paid to attain the higher soluble solids.[17] It is somewhat unclear why soluble solids was only significant during the most recent years since the soluble solids incentives did not changed appreciably over the five year period.

The remaining variables including viscosity (VIS), maturity length (MATURE), color (COLOR), mold (MOLD), yield (YIELD), and multiple use potential (MULT) were found to not significantly influence seed prices. It is not surprising that viscosity and multiple use potential have no impact on seed prices since growers are not paid an incentive to provide these characteristics. There may be no maturity incentive since growers plant varieties which mature at different times to increase their harvesting efficiency, and to reduce their risk and uncertainty. Although growers receive deductions equal to the percentage of mold, it may not have a significant impact on seed prices since the mold level seldom exceeds 2 percent. In addition, most of the varieties experience mold levels that fall within the same narrow range. Color may not significantly affect seed prices because it is difficult to achieve the agtron color reading needed to obtain relatively modest incentives. Finally, yield is an insignificant determinant of seed prices although it plays a dominant role in grower profits. This latter result is especially surprising since growers ranked yield as their most important characteristic.

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[17] During 1995, growers were paid an average of $.8 more per ton if the soluble solids increased from 4.7 to 5.7 percent. Since the average yield in California during 1995 was 33.5 tons, the average per acre soluble solids incentive equaled $27. However, since the average grower uses approximately sixty thousand hybrid seeds per acre, they pay a premium of approximately $40 to increase the soluble solids by 1 percent. Thus, given the above scenario, growers lost an average of $13 per acre on the transaction.

The results at the regional level are similar to the results obtained for the entire state of California. The only variable that was consistently significant in Yolo county at either the 1 percent or 5 percent level was nematode resistance (Table 6.9). Although the San Joaquin data sets were the smallest of the three regions, the results closely mirrored those obtained at the state level (Table 6.10). Finally, the results obtained for Fresno county also were similar to the results obtained at the state level (Table 6.11).

Table 6.9. Implicit Prices of Selected Characteristics of Processing Tomato Varieties Purchased by Yolo County Growers Between 1992-96

	Estimated Coefficients for Selected Years				
Characteristic	1992	1993	1994	1995	1996
Vis	5.00 (.91)[a]	8.80 (1.54)	2.08 (.56)	2.32 (.71)	-2.11 (-.69)
Mature	-1.86 (-.90)	-.57 (-.24)	.05 (.04)	-.63 (-.62)	1.30 (1.21)
Color	5.96 (-.96)	-12.09 (-1.50)	-6.76 (-1.25)	-7.90 (-1.80)***	-2.35 (-.51)
Mold	24.45 (1.20	10.00 (.36)	-2.78 (-.22)	.70 (.08)	-7.20 (-.70)
Solids	-12.99 (-.33)	5.00 (.11)	-8.22 (-.29)	22.16 (1.14)	29.42 (1.31)
Hold	4.35 (.50)	3.21 (.26)	-1.94 (-.28)	-4.92 (-.75)	-3.31 (-.47)
Yield	-1.00 (-.55)	-1.64 (-.85)	-1.26 (-1.01)	.19 (.22)	.58 (.61)
Vine	19.27 (1.47)	16.46 (1.43)	11.42 (1.29)	2.78 (.44)	-2.07 (-.29)
Nema	52.72[b] (2.42)**	62.43 (2.69)**	35.38 (2.50)**	35.25 (3.07)*	61.69 (4.80)*
Mult	-.37 (-.03)	-7.12 (-.54)	-1.95 (-.22)	2.22 (.31)	-1.71 (-.24)
Constant	415.46 (1.48)	336.85 (1.00)	352.75 (1.59)	270.28 (1.49)	-58.66 (-.27)
Adjusted R^2	.08	.13	.02	.13	.28
Lambda	1.0	1.0	1.0	1.0	1.0

[a] The t statistics are placed in parentheses.

[b] A single * indicates that the coefficient is significant at the 1 percent level, two ** indicates it is significant at the 5 percent level, and three *** indicates that the coefficient is significant at the 10 percent level.

Table 6.10. Implicit Prices of Selected Characteristics of Processing Tomato Varieties Purchased by San Joaquin County Growers Between 1992-96

	Estimated Coefficients for Selected Years				
Characteristic	1992	1993	1994	1995	1996
Vis	3.20 (.47)[a]	8.70 (1.22)	7.17 (1.54)	3.94 (.93)	2.66 (.69)
Mature	-4.58[b] (-1.69)***	-1.26 (-.46)	-2.18 (-1.26)	-.45 (-.30)	-.66 (-.44)
Color	-3.59 (-.30)	2.17 (-.27)	10.81 (1.40)	-3.55 (-.56)	-7.18 (-1.45)
Mold	-17.12 (-.52)	-35.55 (-.96)	-8.87 (-.48)	2.36 (.18)	2.86 (.15)
Solids	51.88 (1.46)	4.61 (.11)	46.54 (1.72)***	45.93 (1.64)***	33.78 (1.56)
Hold	13.51 (1.20)	6.12 (.59)	-13.96 (-1.60)	-3.23 (-.39)**	-1.46 (-.22)
Yield	2.75 (1.04)	.58 (.35)	1.23 (.74)	.74 (.44)	-.61 (-.42)
Vine	32.38 (2.17)**	23.37 (1.60)	17.24 (1.76)***	6.99 (.76)	5.66 (.61)
Nema	58.72 (1.74)***	52.93 (1.49)	38.35 (1.75)***	50.54 (2.54)**	49.43 (3.15)*
Mult	-4.46 (-.30)	-12.03 (-.90)	-4.87 (-.48)	-3.30 (-.40)	-3.45 (-.42)
Constant	205.88 (.49)	118.00 (.34)	-267.76 (-.97)	-55.50 (-.23)	199.15 (.89)
Adjusted R^2	.20	.08	.23	.16	.18
Lambda	1.0	1.0	1.0	1.0	1.0

[a] The t statistics are placed in parentheses.

[b] A single * indicates that the coefficient is significant at the 1 percent level, two ** indicates it is significant at the 5 percent level, and three *** indicates that the coefficient is significant at the 10 percent level.

Table 6.11. Implicit Prices of Selected Characteristics of Processing Tomato Varieties Purchased by Fresno County Growers Between 1992-96

	Estimated Coefficients for Selected Years				
Characteristic	1992	1993	1994	1995	1996
Vis	7.87 (1.56)[a]	8.05 (1.71)***	4.33 (1.13)	-.05 (-.01)	-2.27 (-.65)
Mature	.49 (.23)	-.77 (-.43)	-1.72 (-1.28)	-.36 (-.26)	-.11 (-.09)
Color	3.08 (.68)	7.77 (1.38)	-1.51 (-.28)	.92 (.20)	6.30 (1.22)
Mold	-21.72 (-.97)	32.79 (1.81)***	-3.38 (-.21)	-6.34 (.44)	.31 (.02)
Solids	8.06 (.17)	20.31 (.64)	40.87 (1.44)	38.24 (1.66)***	42.43 (1.60)
Hold	1.30 (.17)	5.17 (.94)	-6.33 (-1.14)	-2.28 (-.53)	-4.72 (-.91)
Yield	2.44 (1.31)	.52 (.40)	.72 (.66)	.48 (.42)	.02 (.02)
Vine	25.20[b] (2.21)**	16.81 (1.81)***	9.22 (1.15)	6.01 (.72)	4.21 (.52)
Nema	66.95 (3.02)*	91.60 (4.89)*	48.93 (3.04)*	55.49 (4.04)*	71.34 (5.28)*
Mult	-6.85 (-.52)	-1.59 (-.16)	-.92 (-.10)	-1.51 (-.18)	-2.58 (-.33)
Constant	-352.84 (-1.08)	-344.08 (-1.45)	66.29 (.28)	-55.97 (-.28)	-177.33 (-.86)
Adjusted R^2	.17	.34	.10	.10	.20
Lambda	1.0	1.0	1.0	1.0	1.0

[a] The t statistics are placed in parentheses.

[b] A single * indicates that the coefficient is significant at the 1 percent level, two ** indicates it is significant at the 5 percent level, and three *** indicates that the coefficient is significant at the 10 percent level.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The primary objective of the dissertation was to shed light on how California growers and processors select processing tomato varieties. Each year, PTAB inspects over 200 different processing tomato varieties. The varieties are differentiated by twenty to thirty genetic characteristics that are either important to processing tomato growers or to processors, or the characteristics are important to both parties. Growers are particularly interested in varieties with high yield potential, disease and nematode resistance, superior field holding, specific vine sizes and different maturity lengths. Processors, on the other hand, are interested in varieties which possess excellent color, high soluble solids, high viscosity, multiple-use potential and different maturity lengths. Although they also are interested in yield potential, it is less important to processors than it is to growers since processors obtain the tomatoes they need from many different sources.

Only a few of the varieties inspected by PTAB comprise a significant share of the inspected loads. In most cases the reign of even the most successful varieties seldom lasts for more than a few years. This occurs because processors and growers constantly replace old varieties with new, and supposedly superior, varieties to increase their short-run profits while addressing changes in consumer tastes and preferences. The search by processors and growers for superior varieties is hampered by a number of different factors. First, since growers and processors are interested in somewhat different characteristics, they also are interested in somewhat different

varieties. Second, due to the small differences among the varieties, it is difficult for growers and processors to identify the best variety choices. Third, the performance of varieties in field trials may not reflect how well the same varieties will perform in growers' fields. Fourth, due to the large number of new and old varieties to choose from, growers and processors may lack the resources to adequately sift through the available information to identify the best varieties.

After controlling for the impact processors have on variety selection, the average grower is still able to select from approximately twenty-five processor approved varieties. Intuitively, one would expect the processor approved varieties which earn growers the most profits to have the largest load shares. In addition, since grower profitability and yield are highly correlated, one would expect the highest yielding varieties to have the largest load shares. However, due to numerous possible intervening factors, several of which were mentioned above, these relationships were not observed. Rather, it is hypothesized that there is virtually no correlation between grower profitability and load share. Consequently, yield and profitability play an insignificant role in grower variety selections.

VII.1. Techniques Used to Analyze Variety Selections:

The role important characteristics play in variety selection was analyzed in several different ways. First, growers, processors and other members of the processing tomato industry were surveyed either in person or by mail to learn how characteristics influence variety selection. The survey information was then combined with data collected from variety field trials, PTAB, seed companies, seed dealers and

other secondary sources. The resulting database was then used to estimate variety profitability and the implicit prices (value) of individual genetic characteristics.

The expected profitability of each of the top twenty-five varieties (selected on the basis of load share) were estimated in two stages between 1991 and 1995 at the county (Yolo, San Joaquin and Fresno) and state levels. In stage I, revenues were estimated for each variety by combining information on variety production and contract based incentives and deductions. In stage II, costs were estimated by using crop budgets, prepared by the California Cooperative Extension Service, which were adjusted to account for varietal differences associated with seed, harvest and land rental costs. In stage III, average profits were calculated by subtracting costs from revenues for each targeted variety. The profits were then compared and contrasted to the load shares for the same varieties.

The data sets were then used to estimate the implicit prices of the ten processing tomato characteristics which growers and others identified as being the most important characteristics at the county and state levels between 1992 and 1996. Since the implicit prices of the characteristics are derived from a set of unknown supply and demand functions, several models which employed a Box-Cox power transformation were estimated in an effort to identify the best functional form. After testing several functional forms, the implicit prices were estimated using the classic linear regression model.

VII.1.1. Comparison Between Yield, Profitability and Load Shares

A comparison of the estimated profits and load shares revealed virtually no correlation between variety profitability and load shares among the top twenty-five varieties. At the same time, the correlation between yield and profitability ranged between 82 and 98 percent at the regional and state levels for the same varieties. Since the linkage between yield and load shares is tenuous, yield appears to have little impact on growers' variety choices. This result is surprising for several reasons, First, higher yielding varieties are more profitable for growers. Second, most of the top varieties are included on processor approved variety lists. Third, surveyed growers indicated that yield is their most important varietal characteristic.

There are a number of potential reasons why growers seldom select the most profitable varieties. First, they lack sufficient information to make well-informed variety selections. This partly occurs because there are a large number of varieties to choose from. Second, the mix of varieties available to growers has changed rapidly. Half of all the varieties inspected by PTAB during 1991 were not inspected during 1995. Third, growers may not have adequately used PTAB and field trial data to make variety selections. Surveyed growers ranked their own experiences as the most important source of information followed by data supplied by processors. Field trial data ranked third while PTAB data was ranked the lowest among seven potential information sources. Fourth, growers may choose to use less profitable varieties since they are risk averse and prefer to use varieties which they believe are more reliable and suffer fewer processor deductions. Fifth, some in-house varieties may only be sold to contracted growers. Sixth, growers plant varieties which mature at

different times to maximize their harvesting efficiency and to reduce risk and uncertainty.

VII.1.2. Estimated Implicit Price Results:

The results of the implicit price regressions revealed that most of the ten characteristics which processors and/or growers indicated are important, have no impact on seed prices. In particular, the estimated yield coefficients were not significant at either the county or state levels. The primary characteristics which had significant coefficients were nematode resistance and vine size. Nematode resistance may significantly impact seed prices since only a portion of the varieties contain the characteristic and there are no alternative controls. Vine size significantly affected seed prices since growers increasingly plant tomato seed in single rather than double rows which require a somewhat larger vine. Only a portion of the commercial varieties have large vines.

The coefficients for soluble solids and limited use also were sometimes significant. Limited use has become increasingly important since higher production, coupled with limited processor capacity, has frequently caused growers to delay harvesting their tomato crops. The soluble solids coefficients may have been significant since higher soluble solids reduces processors' production costs. Somewhat surprisingly, soluble solids was the only processor desired characteristic which significantly influenced seed prices. This may indicate that growers have more control over variety characteristics than one might initially believe.

VII.2. Recommendations:

It may be possible to enhance variety selections by improving the type of information which is currently available to growers and processors. Presently, PTAB only collects information on a few of the key quality characteristics which includes soluble solids, limited use, color and mold. It does not collect information on viscosity or the number of tons each variety produces per acre (yield). Although the yield and viscosity information obtained from the field trials is important, it may not accurately reflect varietal performance when the varieties are planted on thousands of acres that are differentiated by soil and weather conditions. In addition, neither the California Cooperative Extension Service nor PTAB collect information on variety field holding. Although the limited-use information collected by PTAB serves as a useful proxy, it may not accurately reflect true field holding ability.

PTAB would be able to collect yield data if growers adopted off the shelf technology designed to enable growers to calculate the number of acres harvested per load of tomatoes. Viscosity can be measured if PTAB develops a system to measure viscosity as quickly and efficiently as they are able to measure mold, color and soluble solids. Field holding should be measured by the Cooperative Extension Service since fields which fail to hold may never be inspected by PTAB.

The improved collection of variety characteristic data would be very useful to processors since it would enable them to carefully regulate the number of loads they require and the varieties to include on their approved variety lists. Growers would benefit since it would reduce the risk and uncertainty they currently experience when they select varieties, and it would enable them to make better variety selections. The

seed industry would benefit since it would allow them to accurately assess the value of their varieties, and improve their ability to set variety prices. It also would help them to formulate their breeding and seed production operations.

VII.3. Study Limitations:

To a large extent the estimated profits are based on yield data which were obtained from the California Cooperative Extension Service field trials. Since the yield data may not accurately reflect actual yields, the estimated profits may not provide an accurate picture of true variety profitability. In addition, growing conditions vary widely from farm to farm and from field to field. Thus, some varieties which on average appear to be unprofitable (profitable), may be profitable (unprofitable) in certain parts of the state or on certain parts of a farm.

The estimated implicit prices also are suspect for several reasons. First, the prices growers actually pay for seed may vary considerably from the suggested retail prices used in the study. Second, some of the characteristic data may not be entirely accurate. This includes the yield data for the same reasons cited above, field holding since limited-use was used as a proxy, and viscosity which was assumed to remain constant over time.

The study also may fail to account for key aspects of variety selection that confound the study results. It is possible that mechanisms exist that make variety selections much more efficient and rational than one may be led to believe by the study results.

VII.4. Recommendations for Future Research:

One of the most important findings of the study is that there are a multitude of factors other than yield and profitability that influence variety selections. Some of the potential factors identified by the study include the harvest schedule, niche and proprietary varieties, intended processed products (paste, peel and/or diced products), processor deductions, grower risk and uncertainty, and limited information on variety characteristics and field performance. The study also found that the importance of each of these potential factors varies from one region to the next.

Until the empirical relationships between variety selection and each of the primary potential factors are clearly understood, growers and processors will continue to face the daunting task of choosing the best varieties from among 300 or more possible choices. If growers and processors, via research, are empowered to understand the empirical relationships, many of the marginal varieties would no longer be purchased, and some of the varieties with large load shares would be replaced by superior alternative varieties. In addition, growers and processors would become more efficient which would, ceteris paribus, increase their profits. At the same time, the prices of processed tomato products at the retail level would fall.

Before empirical research in this area can move forward, the processing tomato industry will need to significantly improve its collection of yield, field holding, viscosity and seed price data by variety. In addition, once improved information becomes available, the model developed for this study could be re-estimated to assess the accuracy of the original findings.

APPENDIX A

APPENDIX A

Mark Phillips
1905 N. Rhodes St. #33
Arlington, VA 22201

Tel: (703) 841-0094
e-mail: 22331MP@MSU.edu

Oct. 11, 1995

Dear Grower:

Over the past 15 years there has been tremendous growth in the number of processing tomato varieties available to growers and processors. Oftentimes a lack of information concerning variety characteristics creates risk and uncertainty regarding how the use of a particular variety will affect grower and industry profits. The purpose of the study is to estimate how individual genetic traits affect the price that growers pay for seed, the price they receive from processors, and the impact characteristics have on yield. The information can then be used by growers and processors to help select the most profitable varieties.

Each of the nearly 500 processing tomato growers in California has been sent a questionnaire to obtain information which is crucial to the success of the project. Although data will be collected from other sources (including seed companies and processors) the information obtained from growers represents the core of the data set. Thus, it is important that each grower complete the questionnaire and return it in the enclosed envelope. All of the individual questionnaire responses will be treated with strict confidence and the respondents will remain anonymous. Participation is voluntary and you may refuse to answer any of the questions. The return envelope has an identification number so that we may check your name off of our mailing list when the questionnaire is returned.

The results of the study will be made available to growers, seed companies, processors, organizations that are involved with the tomato industry, government agencies, and all other interested individuals. You may receive a summary of the results by writing your name and address on the front of the return envelope. If you have any questions please feel free to write or call.

Sincerely,

Mark Phillips

Mark Phillips
Project Director

Mark Phillips
1905 N. Rhodes St. #33
Arlington, VA 22201

Tel: (703) 841-0094
e-mail: 22331MP@MSU.edu

Dec. 5, 1995

Dear Grower:

In late October each of the processing tomato growers was sent the enclosed questionnaire. Although the response was very good we would like to obtain information from the remaining growers to strengthen the study conclusions. Over the past 15 years there has been tremendous growth in the number of processing tomato varieties available to growers and processors. Oftentimes a lack of information concerning variety characteristics creates risk and uncertainty regarding how the use of a particular variety will affect grower and industry profits. The purpose of the study is to estimate how individual genetic traits affect the price that growers pay for seed. The information can then be used by growers and processors to help select the most profitable varieties.

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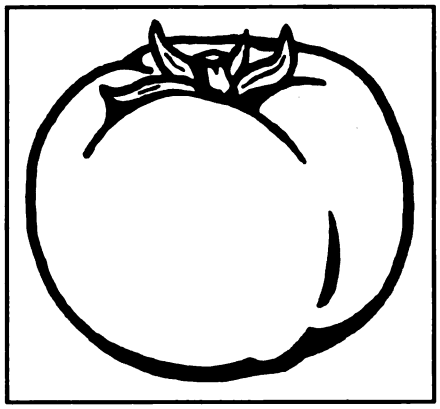
Sincerely,

Mark Phillips

Mark Phillips
Project Director

Grower Survey of the Genetic Resources of Processing Tomatoes



The survey has been designed to obtain information that will be used to assess how varietal characteristics affect the profitability of growing processing tomatoes in California. All of your individual responses will be kept strictly confidential. If you wish to comment on any of the questions please feel free to use the space in the margins or a separate sheet of paper.

The study is sponsored by Michigan State University. Please return the questionnaire in the enclosed stamped envelope.

Q-1 Please list the county(s) where you grow processing tomatoes:

(A) _____

(B) _____

Q-2 To what extent do the prices of hybrid processing tomato seed influence which varieties you purchase? (Check answer).

(A) NO INFLUENCE _____

(B) SOME INFLUENCE _____

(C) STRONGLY INFLUENCES _____

Q-3 Rank from 1-5 the importance of each of the following information sources in making your varietal selections. (Note: assume that *5* is extremely important and that *1* is not important).

(A) VARIETAL TRIALS _____

(B) SEED DEALERS _____

(C) PROCESSORS _____

(D) OTHER GROWERS _____

(E) PTAB DATA _____

(F) SEED COMPANIES _____

(G) OWN EXPERIENCE _____

Q-4 **Rank from 1-5 the importance of each of the traits listed below for achieving grower and processor production objectives (Note: assume that *5* is extremely important and that *1* is not important).**

Characteristic	Rank	
	Grower	Proc-essor
Fruit Color		
Fruit Shape		
Vine Size		
Canopy Type		
Yield		
Bacterial Speck Resistance		
Black Mold Resistance		
Fusarium Wilt Race II Resist.		
Nematode Resistance		
Number of days to maturity		
Field holding		
Viscosity		
Soluble solids (brix)		
Peelability		
Fruit Firmness		
No yellow shoulders		
Stem retention		
Multi-use potential		
Fruit Setting Ability		
Heat Tolerance		
Drought Tolerance		

Q-5 **List (below) by variety the number of acres of each processing tomato variety you harvested during 1995. Also list the approximate gross yield per acre.**

Seed Variety	Acres Harvested	Gross Yield per Acre (Tons)

Q-6 **Using the ordering of seed varieties listed in Q-5 list (below) the prices you paid for each variety you planted during 1995. Also indicate the approximate number of years you have grown each variety.**

Price Per 100,000 Seed ($)	Price Per Pound ($)	Number of Years Grown

Q-7 **Rank from 1-5 the importance of each factor listed below in explaining why you switched some or all of your varieties over the past 5 years (Note: assume that *5* is extremely important and that *1* is not important).**

(A) FIELD HOLDING _____

(B) YIELD _____

(C) DISEASE RESISTANCE _____

(D) STRESS TOLERANCE _____

(E) MATURITY LENGTH _____

(F) LOWER DEDUCTIONS _____

(G) PROCESSOR REQUESTED _____

(H) OTHER_____ _____

Q-8 **How much control do the processors you sell to permit you in selecting the processing tomato varieties you plant each year? (Check answer).**

(A) NONE _____

(B) SOME _____

(C) CONSIDERABLE _____

(D) TOTAL _____

Q-9 **Indicate the approximate number of varieties you are allowed to choose from all of your processor lists considered as a group (check answer).**

(A) 0 _____

(B) 1-5 _____

(C) 6-10 _____

(D) 11-15 _____

(E) 16-20 _____

(F) 21-30 _____

(G) 31-40 _____

(H) 41-50 _____

(I) 51-60 _____

(J) above 60 _____

Q-10 **If you would have chosen some or all different varieties than were chosen by your processor(s) indicate why by checking one or more of the reasons listed below:**

(A) FIELD HOLDING _____

(B) YIELD _____

(C) DISEASE RESISTANCE _____

(D) STRESS TOLERANCE _____

(E) MATURITY LENGTH _____

(F) LOWER DEDUCTIONS _____

(G) OTHER_____ _____

Q-11 **Rank from 1-5 the importance of each of the factors listed below in explaining why you plant more than one variety. (Note: *5* is extremely important and *1* is not important).**

(A) SEED AVAILABILITY _____

(B) HARVEST SCHEDULE _____

(C) EARLY SEASON HARVEST _____

(D) LATE SEASON HARVEST _____

(E) PROCESSOR REQUIREMENTS _____

(F) END USE PRODUCT _____

(G) DISEASE POTENTIAL _____

(H) NEMATODE POTENTIAL _____

(I) SOIL VARIABILITY _____

(J) RAINFALL VARIABILITY _____

(K) EXPERIMENTAL TRIALS _____

(L) OTHER_____ _____

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