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DIVISION OF HORTICULTURE

FACTORS AFFECTING THE AMOUNT OF PUFFING IN TOMATOES

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
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The use of varieties and strains with a high proportion of normal fruit and the development of new low puffing varieties is the best solution of the problem of puffiness in tomatoes. Certain strains of Bonnie Best, Earliana, Kanora, Marketeer, Stone, and Success have been found to have a small amount of puff and are among the varieties being used as parents in breeding work to develop strains with a smaller proportion of puffed fruit. Seed from plants selected for a small amount of puffing produced plants which yielded fruits with decidedly less puff than the seed selected from plants with a large proportion of puffed fruit.

Crossing of varieties tends to reduce puffing, as indicated by the behavior of inter-varietal crosses which show about the same amount of puff as the parent having the smaller amount of puff. Multiple crosses further decrease the tendency to puff, as shown by crossings involving four varieties the first generations of which developed less puffing than those involving any two varieties.

Factors found to affect the proportion of tomato fruits puffed involve variety and strain (hereditary), pollination, available water, temperature, and general nutritional conditions. One or more of these factors may be influenced also by soil type, which in this way may be said to have an influence on the amount of puffing. There appears to be a critical period early in the development of many fruits during which one or more of these factors have an especially important effect. Temperatures above 100°F. increase puffing to approximately 100 per cent, possibly by a reduction in germination and growth of pollen. When maximum temperatures remain below 100°F., lower minimum temperatures appear to favor normal fruit development. Less puff has been found with less available water, and more puff with a greater water supply. On poor sandy soil the addition of commercial fertilizer has reduced the proportion of puff. This was not true on more fertile soil. Most small-fruited varieties have very little puff. Varieties with globe-shaped fruits and few seed cavities are more inclined to puff than varieties with oblate fruits and many seed cavities. Very large fruits that tend to be fasciated are likely to be puffed.

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As early as 1895 in a variety report on tomatoes by H. Ness (12) appears the following comment on the fruit of the Terra Cotta: "(it) is rather a semi-capsule with a leathery covering, reminding one of a pod of sweet pepper rather than of an ordinary tomato" (p. 647). This is an accurate and graphic description of a severe type of what is now commonly called tomato "puff" or "pops".

In defective fruits the seed-bearing tissue does not fill the area within the outer walls completely. In addition, the cross walls may become hard and unpalatable and sometimes grow so as to fill the fruit. Severely affected fruits can be readily identified without cutting because they are angular in shape and somewhat lighter in weight. Figure 1 illustrates these abnormalities. A more detailed description has been published by Traub, Hotchkiss, and Johnson (20).

The defective condition has been observed in the field by Taubenhaus and Ezekiel (17) and by the present writers as soon as the fruit is large enough for examination with a hand lens. Fruits that seem to have developed the defect at a considerably later stage are sometimes found. While it is difficult to get an accurate estimate, it is believed that a high proportion of the affected fruits develop the condition at an early stage.

After careful investigation Taubenhaus and Ezekiel (17, 18) and later Taubenhaus and Altstatt (19) conclude tentatively that the trouble is probably not the result of activity within the plant of a virus or other disease-producing organism. A study of the effect of hereditary and various environmental factors seems to bear this out.

One of the earliest attempts to find a cause for puffing in tomatoes was made by Sando (14) working in Florida in 1919. The investigation, which does not seem to have been carried beyond a preliminary stage, was reported in an appendix to a paper on ripening in the tomato. In a single random crate at a packing house he found 32 normal, 56 partially hollow, and 66 severely puffed fruits. He examined fruit in the field and found that a single plant may have both normal and puffed fruits. He also observed that "there is no stage in the life history of the tomato at which puffiness is a natural occurrence, but it may occur on small as well as large fruit." His work with fertilizers will be discussed later. Since the condition is much worse for the same varieties in Florida than in Michigan, he concludes that "the phenomenon is probably physiological in its nature . . . ." He suggests further that the defect may be due to somatic variation.

An interesting phase of the situation lies in the fact just mentioned, that it seems to be more severe in the South than farther north. It has been referred to in publications of the Arkansas (21), California (10), Florida (22), and Texas stations, and of the United States Department of Agriculture (13). It is an important source of loss to growers of early fruit in this State. The loss from this source has been estimated to be from 5 to 35 per cent of the commercial crop.

Extent of Variation

In a rather extended investigation of puffing in tomatoes it has seemed that the most consistent factor is the high amount of variation obtained. The amount of puffing among different lots may range from 0 to as much as 80 per cent or more, depending upon variety. Different strains of the same variety grown under comparable conditions have ranged from 36 to 77 per cent puff. The same lot may have as high as 78 per cent puff

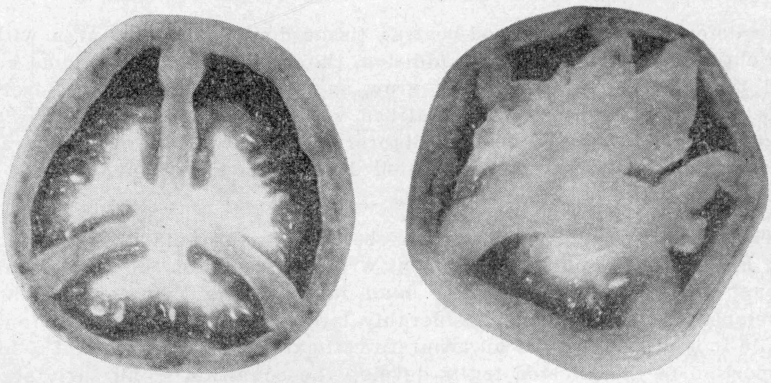

Figure 1. Types of puffing.

during one part of the season and as little as 15 per cent at another period. Similar variations occur for the same strain over a period of several seasons.

This large amount of variation is interpreted to mean that, in addition to the usual amount of variability due to chance sampling, the expression of the defect or characteristic is readily influenced by a large number of factors—hereditary and environmental. These factors may be expected to be interdependent. The immediate problem thus becomes one of determining what the factors are and of estimating their relative importance. Certain evidence has been presented (6, 25) to show that there are important varietal differences which have a hereditary basis. This subject will receive further attention here, as will the results of a study of a number of environmental factors. The latter are harder to identify since they are difficult to control without special equipment. Among environmental factors that might be expected to be of consequence in determining the amount of puffing are available moisture, temperature, humidity, fertility and character of the soil, and amount of wind and sunshine.

Procedure

In an attempt to evaluate the relative importance of the various factors concerned, a number of varieties and strains have been grown in field plats for comparison both at the Main Station in east central Texas and at Substation No. 15 in the Lower Rio Grande Valley. In addition, tests were made of the effect of certain fertilizers and sprays and of varying the water supply. A study of the effect of different weather conditions has also been made.

At College Station, plants were started in a greenhouse, transferred to flats, and set in the field after serious danger of frost was past. All varieties were planted and set in the field at approximately the same time. In a few cases seed received late was planted after the rest. The 1931 planting was earlier than the others. The number of plants per lot varied considerably during different seasons and among the various lots. For the 1935 season 25 plants were grown; this was reduced to 20 in 1936. In certain cases fewer plants were grown because of lack of material. Rows were spaced 3 feet apart with plants 24 or 30 inches in the row.

At Substation No. 15 in the Lower Rio Grande Valley seed was planted in an outdoor seed-bed and the plants were later transferred to a field previously irrigated. The plat consisted of 10 to 25 plants, depending on the type of test. All plants were grown under irrigation as a spring or fall crop. The plants were not pruned or staked in the field at either location.

In the process of securing data each fruit was cut transversely a little nearer the stem than the blossom end and graded according to the severity of the condition. The stage of development of the fruit at time of examination varied somewhat. Much of the fruit was examined before reaching the green-ripe stage, the stage at which it is gathered commercially for early shipment, although data were taken occasionally on older fruits. While it is more difficult to make an accurate classification of ripe fruit because of softness, it will be shown later that, for purposes of comparison, it is more important to use fruits developing over the same period than to examine any particular stage.

In examining the data from the various lots as to possible causes for the variation found, it is first necessary to determine whether or not the difference between any two lots is greater than could be due to chance. The chi square test of independence as outlined by Fisher (4) was found to be a convenient means of determining the significance of such differences in the amount of puffing between two lots. The numbers of normal and puffed fruits for each lot provide data for a four-fold table from which chi square is calculated according to the following formula:

$$\text{Chi square} = \frac{(ad - bc)^2 (a + b + c + d)}{(a + b)(c + d)(a + c)(b + d)},$$

a and b representing the numbers of normal and puffed fruits of one lot and c and d the corresponding numbers of the lot with which the first is

being compared. With a value of 5.4 for chi square the chance is 50 to 1 that the difference between lots is not due to chance but is significant. In most of the tables percentages were not calculated when there were less than 30 fruits per lot. Most lots had between one and five hundred fruits; a few had more. Where fruit numbers are not given, percentages with the superscript (1) had between 50 and 99 fruits; those with (2) had between 30 and 49. In such cases the number of fruits has already been published (25).

RESULTS

Available Water

As is usual in dealing with a plant characteristic responsive to several factors, it has been found difficult to limit the number of variable factors. Observations were made on fairly well controlled moisture experiments in the greenhouse, on less well controlled irrigation experiments in the field, and on the puffing response of tomatoes to different amounts of rainfall.

Greenhouse Experiments: These were carried out at College Station. A comparison was first made between lots receiving two different amounts of water applied in the usual way. Cuttings of Norton Wilt-resistant were grown in galvanized containers 10 inches in diameter and 9 inches deep. The plants were pruned to two stems and staked. The flowers were pollinated by hand. There were eight rows of four plants each. Alternate rows were given the same treatment. The differential waterings began January 13, 1934, and continued to the end of the experiment. The plants watered heavily received, altogether, 213 liters, while those watered lightly were given a total of 130 liters. Fruits were cut when about one-half inch in diameter.

The data are summarized in Table 1. The difference was great for the initial cutting, but the number of fruits was very limited. It will be noted that the percentages of puff based on total fruits are just about

Table 1. Differential water treatments, spring 1934. Based on available fruit for each period.

Data taken	Heavy applications			Light applications		
	Number normal	Number puffed	% puffed	Number normal	Number puffed	% puffed
February 16	0	7	100	5	5	50
February 21-22	9	19	68	7	16	70
March 2	13	24	65	13	21	62
March 13	25	48	67	9	49	84
Total	47	98	67.6	35	91	72.2
Average	.....	.....	75	.....	.....	66.5

the reverse of those obtained by averaging the percentages for each period. This is due to the greater weight of the larger numbers of fruits at the later pickings. If a sample of dependable size had been obtained at each picking, the average amount of puff for each treatment would

have been a more useful figure than the percentage based on total fruit. The alternate flooding and drying out of the soil necessitated by the method of watering would be expected to cover up at least in part any difference due to the differential treatments.

Since the amount of water available to both groups varied widely at different times, the possibility of a constant water supply suggested itself. Plants were grown in vitrified tiles standing in water at different depths, this being the only source of water. In no case was there an attempt to control such factors as temperature, relative humidity, and amount of light. Changes in these factors were presumably the same for all lots. The amount of water available was regulated by the distance to water. The water level is termed "water table" for convenience. The vitrified tile measured 8 inches inside diameter and 38.5 inches long. The flanged end was covered with screen to reduce seepage of soil into the water. The soil was mixed all together with an addition of sand and well-rotted manure. The plants were cuttings of Globe and were carefully graded, each lot of five plants receiving equal numbers of each grade. The experiment was set up November 10, 1934. The plants were pruned to a single stem and trained on a string fastened to wires above, one side branch being allowed to develop later. All flowers were hand pollinated as before.

Figure 2 was made at the time flowers began to develop. It can be seen that the three middle rows were developing faster than the lot with

Figure 2. Differential water treatments in the greenhouse.

the lowest water table. The plants with the highest water table were seriously handicapped. In fact, they grew little more than this during the remainder of the experiment. Free water stood on the surface of the soil of this lot on warm afternoons. The surface of the soil of the lot in the second highest water table showed evidence of moisture at all times. The soil surface of the lot with the lowest water table was fairly dry at

all times. The water containers were kept full, no water being added to the top of the tiles after setting.

While the data are not extensive, there is a decided trend toward increased puffing with a greater water supply (Table 2). By far the great-

Table 2. Differential water treatments—winter 1934-35. Based on total available fruit.

Distance* to water (in.)	Number normal	Number puffed	Per cent puffed
33	21	20	49
29	10	36	78
22	7	31	82
17	8	35	81
5	0	6	100

*From top of tile.

est difference appears between the lot with the lowest water table and the others. The lot with the highest water table has considerably more puff than the others, but the number of fruits is so small as to be of value only as an indication. A comparison of the different lots is made in Table 3. The lot having the highest water table is not included be-

Table 3. Comparison of differential water treatments—winter 1934-35.

Lots compared Water table (in.)	Values of* chi square
33 — 29	8.22
33 — 22	9.27
33 — 17	9.87
29 — 22	0.14
29 — 17	0.13
22 — 17	0.0004

*Values of 5 or more are considered significant.

cause of lack of data. When the lot with the lowest water table is compared with the other three we find a significant difference in each case. When the other three are compared among themselves we find no significant difference.

The third greenhouse experiment, quite similar in setup to the second, was carried out during the spring of 1935. The soil had been left in the tile and was used again without removing. Because of the lack of difference between the three lots with an intermediate distance to the water table, the two highest were made the same and the third was made about the same as the lowest, to give two rows with a low water table and three rows with a relatively high water table. The surface of the water was approximately 33 inches below the top of the tile for the former as before, and about 10 inches for the latter. Seedlings of Master Marglobe (lot 434), the same as those of the field check this season, were used. The plants were graded according to size and distributed among the different rows as before. In addition to this, 10 plants were grown in 10-inch pots

and 15 plants were grown in 4-inch pots. These were watered in the usual manner. The opportunity for the soil to dry out between waterings considerably reduced the amount of water available to these plants. In addition the amount of soil was considerably reduced, particularly in the case of the plants in the 4-inch pots. The experiment was set up April 8, 1935. The plants were pruned to a single stem and were supported with strings as before. All flowers were hand pollinated. The fruits from the high water table lot and those from plants in 10-inch pots were examined when they were between three and four centimeters in diameter. Fruits from the other two were examined when between two and three centimeters in diameter, since it was at first thought that fruits from the lots lacking an abundant water supply might develop slower than the others. This was not the case.

Results, based on total numbers of fruits, are presented in Table 4, with comparisons in Table 5. The difference in the amounts of puff

Table 4. Differential water treatments—spring 1935. Based on total fruit for season.

Treatment	Number normal	Number puffed	Per cent puffed
4-inch pots	25	16	39
10-inch pots	43	70	62
Low water table	36	210	85
High water table	79	312	80

between plants in 4-inch and in 10-inch pots is probably significant, although the value of chi square is low because of the small numbers of fruits from the former group. Plants in pots all had a decidedly lower amount of puff than those in tiles. The two lots having different water

Table 5. Comparison of differential water treatments—spring 1935. Based on total fruits for each lot.

Lots compared	Values of* chi square
4-inch pots—10-inch pots	6.4
4-inch pots—low water table	45.1
4-inch pots—high water table	33.6
10-inch pots—low water table	24.7
10-inch pots—high water table	15.1
Low water table—high water table	3.2

*Values of 5 or more are considered significant.

tables did not have a significant difference in amount of puff, presumably because of two things. The plants with the low water table grew off rapidly and established contact with moist soil at a comparatively early date, thus greatly reducing the difference in the amount of available moisture between the two lots. Conditions were favorable for this comparatively rapid development because of the high humidity accompanying an unusual amount of rainy weather during May, the total rainfall this month amounting to 10.29 inches instead of the 4.67 inches which is the

46-year average for College Station. There was little difference in size of plant between the two lots. During the preceding winter there had been a noticeable size difference between plants with the lowest water table and the others. The second point of explanation has to do with the effect of the high temperature in the greenhouse during late spring and early summer. The results will be discussed in detail under this head.

Irrigation: These experiments were carried out at Substation No. 15, Weslaco. Plats of Cooper's Special were given differential irrigation treatments during the spring of 1928. The plants were grown on Filigonio fine sandy loam. Water was applied by means of an overhead sprinkler system, the amount measured by the use of eight rain gauges. The irrigations were given during March, April, and May. There was .18 inch of rain during March and .66 during April. The May irrigation was made on the first day of the month. A two-inch rain fell on the fifth with a total for the month of 7.44 inches. This nullified the differential treatments for this period. The data are presented in Table 6.

Table 6. Differential irrigation treatments—spring 1928. Percentage of puffed fruit.

Data taken	Treatment prior to May 1 (inches)							
	2.61	7.04	4.52	4.52	5.71	5.71	5.16	5.16
June 7	27	23	31	26	34	32	23	21*
June 16	12	11	16	21	19	41	26	21

*Between 50 and 99 fruits involved; other percentages based on over 100 fruits.

If it is supposed that environmental factors have a greater effect during the early development of the fruit than later, the length of time required for fruit to develop to the stage at which it is examined is an important factor in interpreting results. Sando (14) found that it took 49 days for fruit of the Globe variety to develop to maturity at Arlington, Va., and 56 days for a winter crop at Peters, Fla. Jones and Rosa (8) cite Krassowska (9) as finding that a period of 54 to 65 days is necessary for fruit development in Poland. Fruits under about 35 days old would not be expected to show an influence of differential irrigation because of the rain on May 5. While the ages of the fruits harvested on June 7 are not known, it seems possible that the lack of a consistent difference between the various treatments might be due to the inclusion of a high proportion of fruits developing after May 5.

Differential irrigations were again made during the 1934 season. This time three varieties were used: Chalk's Jewel, Marglobe, and Pritchard. Each treatment was made in duplicate for each variety. One group received irrigation, the other did not. The plat in this experiment consisted of a single row of 20 plants. These plants were grown on the same piece of ground as before. The rows were 6 feet apart with plants 3 feet in the row. The plats receiving water were irrigated on September 25, October 10, and November 17. The rainfall in inches for the last four months of 1934 was 4.63, 1.01, 0.61 and 1.49. There was one rain of as

much as an inch in September, but the rest was distributed in fairly small amounts. Fruits an inch or more in diameter were harvested the first three pickings. All fruits down to one-quarter inch in diameter were harvested the last picking.

The data, grouped according to pickings, are presented in Table 7. It will be noted that for the first picking the unirrigated plats have considerably less puff for each variety. Values of chi square are comparatively low because of small numbers of fruit. With the exception of the

Table 7. Differential irrigation treatments—fall 1934. Based on total fruit for each period.

Variety	Data taken	Irrigated			Unirrigated			Values* chi square
		No. normal	No. puffed	Per cent puffed	No. normal	No. puffed	Per cent puffed	
Chalk's Jewel	Nov. 16.....	51	15	23	25	5	17	2.25
	Nov. 26.....	93	31	25	68	12	15	2.92
	Dec. 8.....	99	14	12	82	11	12	0.015
	Dec. 20.....	361	172	32	366	172	32	0.011
	Total.....	604	232	28	541	200	27	0.11
	Average.....	.....	.....	23	.....	.....	19	
Marglobe	Nov. 16.....	3	13	81	12	6	33	4.83
	Nov. 26.....	16	22	58	7	18	72	1.29
	Dec. 8.....	64	32	33	54	23	30	0.24
	Dec. 20.....	334	292	46	334	197	37	10.7
	Total.....	417	359	46	407	244	38	11.9
	Average.....	.....	.....	55	.....	.....	43	
Pritchard	Nov. 16.....	6	19	76	14	8	36	7.52
	Nov. 26.....	33	21	41	13	27	68	7.53
	Dec. 8.....	78	19	20	55	23	30	2.68
	Dec. 20.....	488	154	24	466	187	29	3.61
	Total.....	605	213	26	548	245	31	4.66
	Average.....	.....	.....	40	.....	.....	41	

* Based on numbers of fruits. Values of 5 or more are considered significant.

second picking of Pritchard and the last picking of Marglobe the later pickings do not show a great deal of difference. The numbers of fruits are small in the case of the exceptional Pritchard data. A comparison of the percentages based on total fruit with the average of the percentages for each picking illustrates how a single heavy picking (December 20) can dominate the season's results based on total fruit. The value of the average, depending as it does upon the securing of sufficient fruit for an adequate sample at each picking, seems to be a better index in this case than that based on total fruit.

During the 1935 season, plats of Gulf State Market, Pritchard, and Scarlet Dawn were given differential irrigation treatments. One group of plats received very light irrigation, one moderate, and one heavy. Data were obtained on October 28, and on November 4 and 14. The percentages of puff based on total fruit harvested are given in Table 8. Gulf State Market made no consistent response. Pritchard had more puff with

Table 8. Differential irrigation treatments—fall 1935. Puffing percentages based on total fruits harvested—Oct. 10, Nov. 4, and Nov. 14.

Variety	Degree of puffing	Type of irrigation		
		Light	Moderate	Heavy
Gulf State Market	Moderate	16	19	12
	Severe	9	9.4	6.8
	Both	25	28	19
Pritchard	Moderate	12	20	21
	Severe	4.2	8.9	12
	Both	16	29	33
Scarlet Dawn	Moderate	25	27	23
	Severe	18	21	25
	Both	43	48	48

increased irrigation for both puffing classifications in about the same proportion. The proportion of moderately puffed fruits of Scarlet Dawn remained about the same while the proportion of severely puffed fruits of this variety increased with greater irrigation.

During the fall of 1936 the irrigation treatments involved Marglobe and Rutgers. All lots were irrigated on September 2 and November 4. In addition, one lot of each variety was irrigated on October 7 and 24. The data may be found in Table 9. For the first two harvests there is

Table 9. Differential irrigation treatments—fall 1936. Puffing percentages based on 100 fruits each harvest.

Variety	Harvest dates								
	November 20			December 3			December 19		
	Mod.	Sev.	Total	Mod.	Sev.	Total	Mod.	Sev.	Total
Marglobe									
2 irrigations	32	2	34	16	4	20	10	20	30
4 irrigations	8	6	14	12	4	16	24	34	58
Rutgers									
2 irrigations	10	2	12	14	8	22	20	14	34
4 irrigations	2	0	2	12	4	16	16	32	48

less puff on those plants receiving the extra irrigations. For the last harvest the situation is reversed. Judging by the values of chi square the percentages for the first two harvest periods of Marglobe are not significant, while the last one is (1.096, 0.27, and 15.9). The corresponding figures for Rutgers are 7.68, 1.17, and 4.05. Since yields of marketable fruit were determined for these plats, the fruits were harvested at about the green-ripe stage. If they took around 60 days to develop as is suggested above, the fruits of the last picking of both varieties set during the effective period of the differential irrigation treatments.

Sprays: During the spring of 1933 two lots of tomatoes, representing duplicate plantings of six varieties were given differential spray treat-

ments, one consisting of a 3-3-50 Bordeaux mixture and the other of the same spray plus 1 gallon of Volk to each 85 gallons of Bordeaux. The application was made on April 24 and the fruits picked at the third harvest, May 22, were classified as to amount of puff. As there was little or no rainfall, the plants were irrigated on March 16, on April 19 and 25, and on May 4. Puffing results are presented in Table 10. It will be seen that in every case there was more puff where Volk had been added to the Bordeaux spray. Judging by the values of chi square obtained there were sufficient fruits to give a significant difference only for Gulf State

Table 10. Effect of differential spray treatments—Weslaco, spring 1933. Based on marketable fruits harvested at third picking, May 22.

Variety	Sprayed with Bordeaux			Sprayed with Bordeaux and Volk			Values* chi of square
	Number normal	Number puffed	Per cent puffed	Number normal	Number puffed	Per cent puffed	
Bonney Best	118	46	28	23	15	40	1.91
Marglobe (a)	43	89	68	6	26	81	2.35
Pritchard	95	95	50	29	58	67	6.81
Ferry's 100	127	42	25	71	39	36	3.64
Gulf State Market	63	52	45	21	68	76	20.2
Marglobe (b)	46	64	53	16	58	78	8.80
Morse 498	106	74	41	66	58	47	0.96
Total	598	462	43	232	322	58	30.8

* Values of 5 or more are considered significant.

Market, Pritchard, and the second lot of Marglobe. When all lots are added together the difference between the two lots is highly significant. In accounting for this difference in amount of puff, it appears that it may be primarily an effect of available water. Wilson and Runnels (24) have found that an application of Bordeaux to tomatoes increases the transpiration rate, while an application of oil decreases transpiration. They also tried equal parts of Bordeaux and a 1 to 100 Volk spray. The latter also reduced the transpiration rate, but less than Volk alone. The mixture reported here had more than twice as much Volk as the one they used and presumably decreased the transpiration rate more, to give a wider differential. This difference in rate of transpiration seems to have affected the rate of puffing in the same way as a difference in soil moisture. A final conclusion can not be drawn, since slight soil differences were involved and the plats were not replicated.

Rainfall: The circumstances of securing data in the field are such that the effect of changes in the weather must be considered with care. For example, grouping data from fruit set several days in succession may cover up, at times, differences due to changes in climatic factors that might otherwise be apparent. During most years at College Station there is a marked decrease in available moisture with the advance of the summer season. Occasionally there is an effective rain in July, which provides an abundance of available moisture. Rather wide differences are to be found between different seasons, but the amount of comparable material from a genetic standpoint is limited. Finally the work has not

advanced far enough to provide an adequate estimate of the effect of the various factors in all cases, particularly any cumulative effect as the season advances. It is believed, however, that a consideration of the data from this standpoint will aid in an understanding of variations in the amount of tomato puff. Data on rainfall and evaporation were secured at the Main Station agronomy farm, at a distance of about a mile and a half from the location of these experiments. This distance introduces a source of error, although probably not serious. These data are given in Table 11.

Table 11. Rainfall and evaporation—College Station.

Type and month	1931	1932	1933	1934	1935	1936
Rainfall (in.):						
March	3.6	.....	.....	.....	.....	.....
April	3.3	2.3	1.9	6.0	3.2	3.3
May	1.9	3.2	4.6	0.4	10.3	7.9
June	1.0	2.8	0.2	0.02	1.4	1.0
July	2.6	0.76	5.0	0.8	4.5	13.3
August	1.0	3.5	6.1	1.2	1.7	1.9
Evaporation (in.):						
March	4.4	.....	.....	.....	.....	.....
April	3.8	4.7	5.1	4.2	3.8	4.9
May	6.2	5.3	5.9	6.3	3.9	4.6
June	6.7	5.6	7.7	8.9	5.4	7.0
July	6.2	7.6	7.2	9.3	6.9	6.0
August	7.1	6.8	6.1	8.0	7.3	6.4

The percentages of puff observed at College Station during May and June 1931, as presented in Table 12, reveal that there has been either less puff later in the season or no significant change. For 1931 there is

Table 12. Comparison of varieties and period of fruit development—College Station, 1931. Based on total fruit for each period.

Variety	May % puff	June % puff	Values* of chi sq.	Significant change
Bonny Best	24	23	0.015	0
Break O'Day	38	20	40.9	—
Cooper's Special	78	15	168.2	—
Earliana	29.9	33	0.97	0
Fargo	25	16	12.3	—
Gulf State Market	33	11	31.6	—
June Pink	18	16	0.66	0
Marglobe	64	62	4.0	—(?)
Total	37.0	25.5	12.5	—

* Values of 5 or more are considered significant.

little difference in rainfall and amount of evaporation between May and June or little difference between March and April, but a marked difference between April and May. The rainfall dropped from 3.3 inches in April to 1.9 in May while the accumulated evaporation rose from 3.8 in April to 6.2 in May. This would seem to give a considerably smaller amount of water available to the plant during May than during the preceding month. It seems fair to assume that the fruits harvested in May thus set and developed under conditions providing more available moisture than those examined in June 1931. Only one variety had more puff

Table 13. Comparison of varieties and period of fruit development—College Station, 1932. Based on total number of harvestable fruits for each period.

Variety	Lot No.	Per cent puffed fruit						Values[3] of chi square	Significant change
		June			July				
		Mod.	Severe	Total	Mod.	Severe	Total		
Acme	67	16	4.3	20	8.2	0.1	8.4	41.7	—
Bonny Best	7	26	4.2	31	22	1.0	23	3.20	0
Bonny Best	33	37	14	52	42[1]	0.0[1]	42[1]	1.74	0
Bonny Best	39	23	6.2	29	15	0.0	15	18.1	—
Bonny Best	68	28	7.8	35	21	0.6	27	3.78	0
Break O'Day	2	39	11	50	27	0.3	27	46.6	—
Break O'Day	14	46	5.2	52	33	1.7	34	14.7	—
Break O'Day	20	38	10	49	26	0.0	26	43.3	—
Break O'Day	43	39	11	50	26	0.2	26	69.4	—
Cooper's Special	69	34	23	57	30	6.2	37	35.8	—
Dwarf Champion	70	32	8.7	40	22	0.7	23	20.6	—
Earliana	1	35	15	50	27	0.0	27	53.4	—
Earliana[4]	12	16	2.3	18	10	0.4	10	6.91	—
Earliana	45	33	24	57	24	0.4	24	23.9	—
Earliana[4]	46	27	9.6	37	16	0.5	17	21.6	—
Early Detroit	5	21	6.8	27	15	0.5	15	33.5	—
Early Stone	19	35	16	50	36	8.4	44	8.69	—
Globe	8	35	26	61	33	5.5	39	18.2	—
Globe	13	26	10	36	24	7.4	32	0.46	0
Globe	23	40	26	66	38	6.0	44	22.8	—
Globe	72	31	46	77	39	18	57	8.92	—
Greater Baltimore	17	19	1.7	21	25	1.7	27	2.97	0
Greater Baltimore	31	24	2.7	27	27	1.7	29	0.577	0
Gulf State Market	10	28	13	40	13	0.7	13	62.1	—
Gulf State Market	27	31	15	46	19	0.9	20	20.5	—
Gulf State Market	32	36	16	53	24	9.7	34	18.5	—
Gulf State Market	73	19	5.5	24	11	1.4	13	24.1	—
John Baer	6	22	3.5	26	13	0.0	13	32.8	—
Louisiana Pink	37	22	24	46	32	14	45	0.0043	0
Marglobe[5]	3	42	24	67	53	15	68	3.87	0
Marglobe	11	24[2]	58[2]	82[2]	47[1]	32[1]	79[1]	0.159	0
Marglobe	15	45	30	74	46	16	61	37.96	—
Marglobe	24	57	16	73	49	8.3	58	7.888	—
Marglobe	28	44	15	59	56	7.6	64	0.187	0
Marglobe	30	38[1]	38[1]	77[1]	49	24	73	0.37	0
Marglobe	40	42[1]	36[1]	78[1]	45	22	67	3.44	0
Marglobe	41	37	46	83	47	23	70	40.1	—
Marglobe	44	46	25	71	49	9.5	59	29.7	—
Marglobe	47	48	28	76	49	16	66	4.72	—
Marglobe[5]	55	32[1]	23[1]	55[1]	47	9.9	57	0.113	0
Matchless	25	39[2]	20[2]	59[2]	28[1]	4.4[1]	32[1]	8.36	—
Mississippi Girl	4	32	9.8	41	20	0.0	20	17.8	—
Norton	22	41	13	54	37	1.0	38	11.8	—
Norton	35	41	18	58	27	0.0	27	7.66	—
Ponderosa	75	56[2]	14[2]	70[2]	38[1]	0.0[1]	38[1]	12.0	—
Pritchard	49	..	..	..	49	6.6	55	....	..
Stone	9	35	8.3	43	28	1.5	29	13.3	—
Stone	16	..	..	..	51	9.9	60	....	..
Stone	76	30	14	44	28	6.5	34	7.92	—
Success	21	26	3.7	30	20	3.8	24	1.01	0
Total[6]	.....	31	13	44	28	4.7	33	44.0	—

1 Based on between 50 and 99 fruits.
2 Based on between 30 and 49 fruits.
3 Based on total numbers of normal and puffed fruits for each period. Values of 5 or more are considered significant.
4 "June" data taken first few days in July.
5 Fertilized with 6-12-6 at the rate of 1800 lbs. per acre.
6 Total only of lots harvested both months.

Table 14. Comparison of varieties and period of fruit development—College Station, 1933. Based on total number of harvestable fruits each period.

Variety	Lot No.	Per cent puffed fruit						Values[3] of chi square	Significant change
		July			August				
		Mod.	Severe	Total	Mod.	Severe	Total		
Acme	103	17	0.0	17[2]	14	0.0	14	0.29	0
Albino	42	38	6.3	44[2]	64	0.0	64[1]	3.59	+(?)
Albino	194a	70	1.4	70[1]	66	0.0	66	0.63	0
Albine	194b	61	0.0	61[2]	68	5.2	73	1.96	0
Bonny Best	33	7.7	0.3	8.0	15	0.2	15	9.82	+
Bonny Best	39	9.6	1.9	12[1]	17	0.0	17[1]	0.65	0
Bonny Best	106	8.8	0.9	9.7	21	0.0	21	27.96	+
Bonny Best	107	7.1	0.0	7.1[1]	25	0.0	25	14.1	+
Bonny Best	108	13	1.8	15	17	0.0	17	0.36	0
Break O'Day	20	26	8.6	35	27	0.0	27	4.83	—(?)
Break O'Day	43	19	2.7	22	30	0.0	30	5.87	+
Break O'Day	112	26	3.2	30[1]	25	0.0	25[1]	0.47	0
Cherry, Red	189	0.0	0.0	0.0	0.0	0.0	0.0	....	0
Cherry, Yellow	188	0.0	0.0	0.0	0.0	0.0	0.0	....	0
Current, Red	196	0.0	0.0	0.0	0.0	0.0	0.0[1]	....	0
Cooper's Special	113	14	1.2	16[1]	37	0.5	38	14.1	+
Cooper's Special	114	18	1.7	20	39	0.7	39	25.7	+
Dwarf Champion	115	18	2.7	20	19	0.5	19	0.22	0
Dwarf Champion	116	12	1.7	13	19	0.0	19	2.44	0
Dward Champion	117	20	1.2	22	11	0.0	11	25.6	—
Rarliana	118	19	2.7	21	26	0.0	26	1.14	0
Earliana	119	12	0.0	12[1]	17	0.0	17[2]	0.65	0
Earliana	122	12	0.0	12[1]	..	0.0	..	....	—
Earliana	123	25	1.1	26[1]	16	0.0	16[1]	2.66	0
Early Detroit	5	9.0	0.0	9.0	24	0.5	24	19.6	+
Early Detroit	124	9.2	0.6	9.8	12	0.0	12	0.498	0
Early Detroit	127	10	1.5	12[1]	6.4	0.0	6.4	1.58	0
Early Stone	164	15	2.8	18	56	2.9	59	178.9	+
Early Stone	165	15	2.1	17	62	3.9	66	277.9	+
Early Stone	166	20	0.8	20.4	54	3.0	57	127.5	+
Early Tree	197	30	0.5	31	29	0.2	29	0.83	0
Giant Climbing	195	39	0.0	39[1]	83	0.0	83[1]	36.6	+
Globe	130	27	0.0	27[2]	40	0.0	40	3.15	+(?)
Globe	132	4.7	0.8	5.4	11	0.0	11	5.47	+
Globe	135	32	2.7	35	32	3.4	36[1]	0.002	0
Greater Baltimore	145	8.1	0.2	8.3	19	0.6	20	27.1	+
Greater Baltimore	146	9.6	0.8	10	39	0.0	39	49.9	+
Gulf State Market	10	2.9	1.5	4.4[1]	38	0.0	38	27.0	+
Gulf State Market	32	7.2	2.1	9.2	28	0.0	28	38.5	+
Gulf State Market	139	6.4	0.4	6.8	16	0.3	17	25.0	+
Gulf State Market	140	16	0.8	17	40	0.8	41	75.9	+
Gulf State Market	142	11	2.8	14	34	0.9	35	46.4	+
Gulf State Market	144	7.3	3.6	11	33	0.5	33	23.1	+
John Baer	150	8.3	0.0	8.3	11	0.0	11	1.04	0
Kanora	26a	11	1.3	13	22	0.2	23	13.1	+
Kanora	26b	18	0.0	18[1]	36	0.7	37	7.20	+
Karger	191	13	2.0	15	17	0.0	17	1.00	0
Lloyd Forcing	50	8.6	0.0	8.6	25	0.0	25	38.6	+
Lloyd Forcing	51	9.1	2.3	11	29	0.5	29	21.2	+
Lloyd Forcing	169	22	4.4	26	39	1.7	41	14.2	+
Lloyd Forcing	170	13	1.4	15	24	1.4	26	14.5	+
Lloyd Forcing	171	12	1.1	14	28	0.0	28	21.2	+
Lloyd Forcing	172	12	1.2	13	17	0.2	17	5.22	+
Lloyd Forcing	187	2.9	0.9	3.8	24	0.0	24	23.8	+

Table 14. Comparison of varieties and period of fruit development—College Station, 1933. Based on total number of harvestable fruits each period.—Continued

Variety	Lot No.	Per cent puffed fruit						Values[3] of chi square	Significant change
		July			August				
		Mod.	Severe	Total	Mod.	Severe	Total		
Marglobe	40a	..	..	..	54	1.0	55	....	—
Marglobe	40b	29	7.1	36	52	1.1	53	20.2	+
Marglobe	40c	28	7.0	35	47	0.6	48	10.7	+
Marglobe	40d	39	4.1	43	56	1.7	58	7.78	+
Marglobe	41	30	2.6	33	50	0.4	50	28.1	+
Marglobe	152	21	0.0	21	25	0.6	25	0.95	0
Marglobe	153	30	9.3	40[2]	51	0.0	51[1]	1.34	0
Marglobe	154	34	0.0	34[2]	33	0.0	33[2]	0.03	0
Matchum	158	12	0.4	13	25	0.7	26	18.9	+
Matchum	159	19	0.0	19[2]	23	0.0	23	1.08	0
Mexican Husk	192	3.7	0.0	3.7	2.4	0.0	2.4	0.52	0
Norton	35	17	0.0	17[1]	18	0.0	18	0.021	0
Norton	160	19	1.4	20	46	1.8	48	75.2	+
New Self Pruning	181	2.3	0.0	2.3[2]	36	1.7	37	19.3	+
Peach	179	4.4	0.3	4.7	32	0.0	32	92.1	+
Pear, Italian	183	2.7	0.4	3.1	5.5	0.0	5.5	1.59	0
Pear, Yellow	180	0.0	0.0	0.0	0.0	0.0	0.0	....	0
Plum, Red	189	..	..	..	1.3	0.0	1.3	....	—
Pritchard	162	29	1.1	30[1]	58	0.0	58	15.6	+
Pritchard	163	24	5.5	30	49	1.5	30	10.3	+
Prune	186	7.0	1.8	8.8	0.2	0.0	0.2	36.8	—
Prune	193	2.1	1.0	3.1	0.0	0.0	0.0	....	--(?)

1 Based on between 50 and 99 fruits.

2 Based on between 30 and 49 fruits.

3 Based on total numbers of normal and puffed fruits for each period. Values of 5 or more are considered significant.

in June than during the preceding month and this slight increase was well within the limit of chance variation. This and two other varieties showed no significant difference. Four varieties, possibly five, had significantly less puff. The value of chi square for all eight varieties is 12.5, indicating a significant difference.

This reduction in rainfall with increase in accumulated evaporation as the summer season progresses represents the usual trend at College Station. In 1932 when the data were secured in June and July instead of in May and June as before, we find that 46 out of 51 lots, representing 20 varieties, had less puff later in the season (Table 13). This difference was significant in 34 cases out of the 46. The other differences are not more than might be due to chance. There was a greater reduction in the amount of severely puffed fruits during the second harvest period than of those classified as moderately puffed. Even for those cases where there was little or no difference between the two periods in total amount of puff there was a much smaller proportion of severely puffed fruits later in the season (see Louisiana Pink and Total). This season (1932) the reduction in rainfall from May to June was less than in the preceding year but dropped to only .76 of an inch during July. The fruits harvested during July thus set and developed under progressively drier conditions than those harvested the preceding period.

During 1933 the trend was reversed. In 39 instances there was a significant increase in the amount of puffing, with two additional lots that may have had a significant increase. In only 2 cases, including a small-fruited variety, was there a significant decrease; two others may be significant. Of the lots which did not change materially, 13 had a slight increase, 9 had a decrease, and 6 remained unchanged, 4 of which, being small-fruited, had no puff (Table 14).

There was an unusually small amount of rainfall (0.24 inches) during June 1933, while during July there was an unusually large amount (5 inches). Fruits for the first period were cut from about June 10 to July 10, those for the second period from July 15 to August 10. Many of the fruits examined during the first period thus set and developed under much drier conditions than those examined during the second period. This general increase was for the most part due to an increase of moderately puffed fruit. Considering the class of severely puffed fruits we find a decrease from July to August in 44 cases, an increase in 12 cases, and no change in 18 lots.

Table 15. Comparison of puffed fruit during three periods—College Station, 1934. Based on total number of harvestable fruit for each period.

Variety	Lot No.	June		July		Fall		Per cent puffed		
		No. normal	No. puffed	No. normal	No. puffed	No. normal	No. puffed	June	July	Fall
Bonny Best	226	23	10	14	25	0	1	30	64	..
Bonny Best	227	12	2	15	45*	159	72	..	75	31
Bonny Best	228	17	2	25	150*	105	41	..	86	28
Dwarf Champion	241	16	7	49	19*	30	7	30	28	19
Early Detroit	245	15	1	23	22	14	6	..	49	..
Globe	129	8	0	1	5	15	28	..	..	65
Globe	248	22	0	24	13	10	10	..	35	..
Gulf State Market	136	2	1	5	11	121	21	..	..	15
Gulf State Market	138	2	0	12	13	121	17	..	52	12
Gulf State Market	205	..	..	0	3	114	49	..	..	30
John Baer	148	17	1	21	12	47	16	..	36	25
Kanora	201	2	0	3	7	137	16	..	..	11
Lloyd Forcing	279	9	1	3	20*	76	16	..	87	17

*Includes data secured during the first few days of August.

The 1934 summer season was exceptionally hot and dry. For this reason the amount of data was very limited and, since the observations were scattered over an unusually long period of time, comparisons are of doubtful value. As can be seen from Table 15, in many cases too few data were obtained for an accurate estimate of the amount of puffing for several lots during certain periods. It will be noticed that the percentage of puffed fruits developing during the dry period in the summer is, in general, greater than for fruits developing after the drought had been broken. There were 4.41 inches of rain during September, which stimulated the heaviest set of fruit that season. It seems likely that high temperatures rather than moisture differences may have been the de-

termining factors. The data will be considered further under the subject of temperature.

In order to determine the amount of variation to be expected from replicated plantings and to have a check for comparison with other lots, Stoke's Master Marglobe (lot 434) was grown at regular intervals throughout the entire planting at College Station in 1935. The plats consisted of single rows of 25 plants each. The first plat of each row was lettered A in addition to the row number; the second plat of each row was lettered B, and so on. This lot of Marglobe occupied a plat in every sixth row, arranged so as to checker-board the field. Thus plats 2A, 8A, 5B, 11B, and so on, were Marglobe No. 434. The entire planting was 19 rows wide with 6 plats lengthwise across the field, the last group of plats having 15 instead of 25 plants.

The soil is classified as Lufkin fine sandy loam. It is evident that it is slightly heavier at the eastern end of the field, including the F plats and a part of the E. The rest of the field appears to be quite uniform.

The numbers and percentages of puffed fruits for these 17 replications are presented in Table 16. The data for the first pickings can be arranged

Table 16. Replications of Marglobe 434—College Station, 1935. Based on total fruit for each period.

Plat No.	First picking			Second picking			Per cent puffed	
	Data taken	Number normal	Number puffed	Data taken	Number normal	Number puffed	First	Second
2A	June 11	38	97	July 12	208	106	72	34
8A	" 13	45	137	" 12	326	101	75	24
5B	" 13	33	134	" 15	290	126	80	30
8C	" 13	28	111	" 16	292	78	80	21
11D	" 13	37	82	" 16	156	21	69	12
14E	" 13	26	68	" 17	213	50	72	19
14A	" 17	63	147	" 12	181	178	70	50
17B	" 25	111	99	" 16	76	40	47	35
2C	" 26	140	151	" 16	127	148	52	54
5D	" 27	131	109	" 16	36	22	45	38
17D	July 1	109	65	" 17	18	7	37	.....
8E	" 4	113	75	" 17	28	6	40	17
2E	" 5	180	126	" 17	103	65	41	39
5F	" 5	100	43	" 17	35	15	30	30
11F	" 6	53	19	" 17	9	9	26	.....
11B	" 9	144	63	.....	.....	.....	30	.....
14C	" 12	108	19	" 16	6	7	15	.....

in four groups according to the date the records were taken. The amount of puff over the period June 11 to 17 inclusive ranges from 68.9 to 80.2 per cent with an average for seven plats of 74 per cent. Data gathered June 25, 26, and 27 have a lower percent of puff—from 45.4 to 51.9—with an average for the three plats of 48.2 per cent. Data for six plats were taken from July 1 to 9 inclusive. The range in this case is from 26.4 to 39.9 per cent, with an average of 34.1 per cent. The remaining plat had 15 per cent puff.

A comparison between these figures and the rainfall five weeks previous is made in Figure 3. It will be seen that there is an ample amount of moisture early in the season, with a decreasing amount later, the decrease corresponding roughly to the decrease in the amount of puffing. In general, the plats picked later were a little slower in developing because of uneven seedling growth before setting in the field.

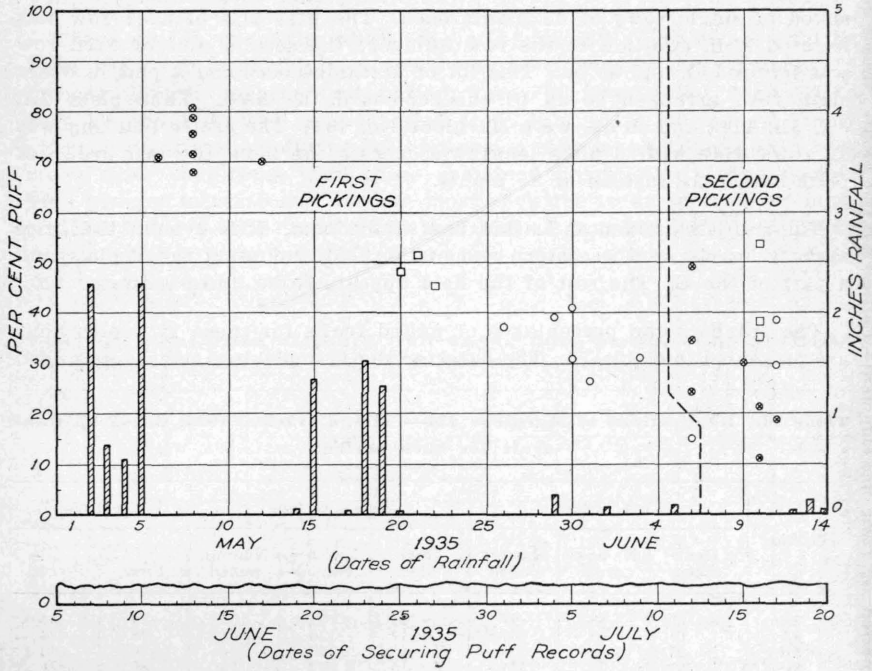

Figure 3. Comparison of rainfall at about the time of fruit setting with per cent of puff at harvest. Marglobe No. 434. College Station, 1935.

Greater variation was found among lots at the second picking. For the plats picked first from June 11 to 17 there was a marked reduction at the second picking. For those picked after June 25, which already had a reduced amount of puff, there was less difference or none at all between the two harvest periods.

Lot 414, a selection of a varietal cross, was grown in four adjacent plats during the same season. Data were taken on plats 4A and 7A on June 11 and 13 respectively, on plats 5A and 6A on June 29 (Table 51). Percentages of puff for the former are 24 and 27 and for the latter 7.1 and 7.2. These four plantings were set the same day and developed equally. It was the original intention to secure data only from 4A and 7A; for this reason, puffing data were not obtained for the early fruits of 5A and 6A. This explains the lower number of puffed fruits for these lots. Fruits from all four plats were examined on July 12. The relative percentages of puff were reversed at this time. Those lots whose fruits developed over the same period had about the same amount of puffing.

Table 17. Comparison of varieties and period of fruit development—College Station, 1935. Based on total fruit for each period.

Variety	Lot No.	Location	First period				Second period				Per cent puffed		Values* of chi square	Change
			Data taken	No. normal	No. puffed		Data taken	No. normal	No. puffed		First	Second		
					Mod.	Severe			Mod.	Severe				
Alpha	447	13C	June 28..	330	40	3	July 16..	40	5	0	12	11	0.0006	0
Avon	498	18B	" 21..	168	108	2	" 16..	23	9	0	40	28	1.59	0
Beauty	487	16C	July 1..	118	58	1	" 16..	64	12	0	33	16	8.11	—
Beefsteak	503	12A	June 17..	39	103	10	" 12..	44	163	8	74	80	2.75	0
Bloomsdale	491	4B	" 26	130	38	2	" 15..	89	54	0	24	38	7.49	+
Bloomsdale	491	16F	July 6..	90	10	0	" 17..	9	1	0	10	.....	.....	.....
Bonny Best	330	3A	June 11..	245	99	8	" 12..	153	27	0	30	15	15.0	—
Bonny Best	332	3B	" 22..	226	57	7	" 15..	86	42	1	22	33	5.96	+
Bonny Best	336	3C	" 26..	218	46	1	" 16..	19	4	0	18	.....	.....	.....
Bonny Best	342	3E	July 4..	255	67	9	" 17..	2	3	0	23	.....	.....	.....
Bonny Best	484	16A	June 17..	233	73	5	" 15..	106	25	0	25	19	1.85	0
Break O'Day	492	17A	June 21..	166	90	5	" 15..	127	59	2	36	32	0.72	0
Brimmer	444	13A	" 17..	29	96	3	" 12..	22	94	4	77	82	0.71	0
Canadian	452	14D	July 3..	221	45	1	" 17..	10	0	0	17	.....	.....	.....
Chalk's Early	450	13F	" 6..	179	26	0	" 17..	9	5	0	13	.....	.....	.....
Clark's Special Early	499	18C	June 29..	172	23	0	" 16..	15	0	0	12	.....	.....	.....
Cleft	439	11A	" 17..	35	44	13	" 12..	58	71	0	62	55	1.05	0
Delaware Beauty	493	17C	" 29..	142	30	1	" 16..	47	5	0	18	9.6	2.45	0
Dwarf Champion	347	6B	July 6..	139	30	1	" 15..	35	10	0	18	22	0.42	0
Dwarf Champion	350	7B	June 26..	195	63	0	" 15..	118	5	0	24	4.1	23.8	—
Dwarf Champion	351	8B	" 26..	48	15	2	" 15..	88	10	0	26	10	7.19	—
Dwarf Champion	413	10A	" 13..	87	80	3	" 12..	227	16	0	49	6.6	10.2	—
Dwarf Champion	413	12D	July 2..	237	23	0	" 17..	73	3	0	8.8	3.9	1.98	0
Earliana	440	10E	July 4..	191	16	0	" 17..	38	2	0	7.7	5.0	0.37	0
Earliana	453	15A	June 17	282	126	7	" 15..	48	7	0	32	13	8.67	—
Earliana	500	1E	July 5..	29	15	0	" 17..	0	1	0	34	.....	.....	.....
Early Detroit	353	9A	June 13..	235	63	3	" 12..	308	33	0	22	9.7	18.4	—
Early Detroit	355	12A	" 17..	24	5	1	" 12..	35	3	0	20	7.9	2.14	0
Early Detroit	358	11A	" 17..	21	0	0	" 12..	6	2	0	.....	.....	.....	.....
Early Detroit	504	18F	July 6..	108	6	0	" 17..	9	0	0	5.3	.....	.....	.....
Early Stone	411	1A	June 11..	7	7	3	" 12..	33	26	1	.....	45	.....	.....
Florida Special	435	10C	" 28..	110	11	0	" 16..	3	1	0	9.1	.....	.....	.....
Globe	368	1F	July 5..	156	40	0	" 17..	16	2	0	20	.....	.....	.....
Globe	368	6F	June 27..	130	14	1	" 17..	4	2	0	10	.....	.....	.....

* Values of 5 or more are considered significant.

Table 17. Comparison of varieties and period of fruit development—College Station, 1935. Based on total fruit for each period.—Continued

Variety	Lot No.	Location	First period				Second period				Per cent puffed		Values* of chi square	Change
			Data taken	No. normal	No. puffed		Data taken	No. normal	No. puffed		First	Second		
					Mod.	Severe			Mod.	Severe				
Golden Queen	454	15B	June 25	284	52	5	July 16	254	24	0	17	8.6	8.80	—
Grothen Globe	436	4D	" 27	86	85	4	" 16	36	37	0	51	51	0.001	0
Gulf State Market	380	6D	" 27	340	18	0	" 16	23	0	0	5.0	.....	.....	.....
Gulf State Market	384	6E	" 27	297	58	2	" 17	100	19	1	17	17	0.013	0
Gulf State Market	386	8D	July 2	81	12	0	" 16	2	2	0	13	.....	.....	.....
Gulf State Market	387	9D	" 2	254	32	0	" 16	23	0	0	11	.....	.....	.....
Gulf State Market	388	10D	" 2	242	29	0	" 17	57	2	0	11	3.4	3.04	0
John Baer	359	1B	" 6	30	4	0	" 15	9	4	0	12	.....	.....	.....
John Baer	362	9C	June 28	24	2	0	" 16	.....	.....	.....	7.7	.....	.....	.....
John Baer	363	8B	" 26	53	9	0	" 15	30	1	0	19	3.2	2.75	0
John Baer	364	8B	" 26	30	3	0	" 15	1	1	0	9.1	.....	.....	.....
John Baer	457	15E	" 27	280	35	1	" 17	27	4	0	11	13	0.063	0
John Baer	501	18D	July 1	279	21	0	" 17	8	1	0	7.0	.....	.....	.....
June Pink	505	19A	June 21	164	84	1	" 15	35	2	0	34	5.4	12.6	—
Kanora	366	10B	" 22	309	41	2	" 15	118	1	0	12	0.8	13.6	—
Landreth	494	17E	July 3	210	29	1	" 17	3	1	0	13	.....	.....	.....
Lloyd Forcing	389	9E	" 4	305	76	6	" 17	37	0	0	21	0.0	.....	.....
Lorillard Forcing	448	13D	" 3	134	21	0	" 17	80	6	0	14	7.0	2.40	0
Louisiana Pink	446	13B	June 22	285	141	14	" 16	116	30	0	35	21	10.9	—
Marglobe	441	5E	July 4	131	111	4	" 17	70	51	0	46	42	0.692	0
Marglobe	495	8B	June 26	42	37	1	" 15	7	18	0	48	.....	.....	..
Marglobe	495	8D	July 2	65	44	3	" 16	18	7	0	42	.....	.....	..
Marketeer	451	14B	June 24	278	51	1	" 16	37	6	0	16	14	0.943	0
Matchless	488	16D	July 1	167	34	1	" 17	67	10	0	17	13	0.776	0
Matchum	266	5C	June 26	172	49	1	" 16	8	0	0	23	.....	.....	.....
M. O.	442	10F	July 5	16	27	14	" 17	14	6	0	72	.....	.....	.....
Norana	443	7D	" 2	64	49	1	" 16	31	25	0	44	45	0.009	0
Oxheart	506	19B	June 25	4	35	14	.....	.....	.....	.....	94	.....	.....	.....
Peach	458	15F	July 6	153	7	0	" 17	148	2	0	4.4	1.3	2.54	0
Pennsylvania State	509	19E	" 3	154	38	0	" 17	14	1	0	19	.....	.....	.....
Pear, Italian	456	15D	" 1	572	53	0	" 17	91	5	0	8.5	5.2	1.20	0
Plum	496	17F	" 6	150	0	0	" 17	120	0	0	0.0	0.0	.....	0
Pomadora	485	16B	June 25	443	199	72	" 16	407	19	2	38	4.9	15.6	—
Pritchard	502	18E	" 27	180	121	2	" 17	91	9	0	41	9.0	48.9	—
Red River	449	13E	July 3	115	46	1	" 17	10	2	0	29	.....	.....	.....
Red Rock	489	11C	June 28	96	37	2	" 16	28	12	0	29	30	0.18	0
Redfield Beauty	437	1D	July 2	57	30	1	" 16	21	0	0	35	.....	.....	.....
Royal Purple	490	16E	" 1	126	30	2	" 16	59	5	0	20	7.8	5.09	—
Rutgers	438	1A	June 11	55	58	20	" 12	168	111	2	59	40	12.3	—
Scarlet Dawn	508	19D	" 29	91	60	6	" 17	15	12	0	42	44	1.05	0
Success	455	15C	" 28	330	41	1	" 16	36	4	0	11	10	0.061	0

The evidence from lot 415 shows the same thing. Data taken on 12B on June 22 show twice as much puffing as data on 7C and 12C taken on June 28. The data for the last four lots (7C, 12C, 3D, 7E), taken over a period of 6 days, are in substantial agreement and differ from data taken only 6 days earlier. A change in environmental factors seems to be a likely explanation. It would seem that records taken on different days may or may not be comparable, depending on the time involved and on the rate of change of environmental factors during the effective period.

The very exceptional rainfall of 10.29 inches occurred during May of 1935; then comparatively dry and wet months alternated. Under such circumstances, the result for any period depends upon the proportion of fruits developing under the various conditions which are included. For this reason, examination dates have been given. A comparison of the two periods of Table 17 shows that there was significantly more puff during the second period in but 2 cases, while there was significantly less puff for 16 lots. In addition, all but one of the check plats mentioned above had less puff during the second period. Of the 30 instances in which the change was no greater than might be due to chance, 17 had less puff the second period. A number of these had a marked reduction during the second period but, as in the case of Avon, it seems likely that chi square was not high because of the small numbers of fruit. Nine others had more puff and 4 showed practically no change. The reduction in puffing presumably reflects the difference in available moisture between May and June.

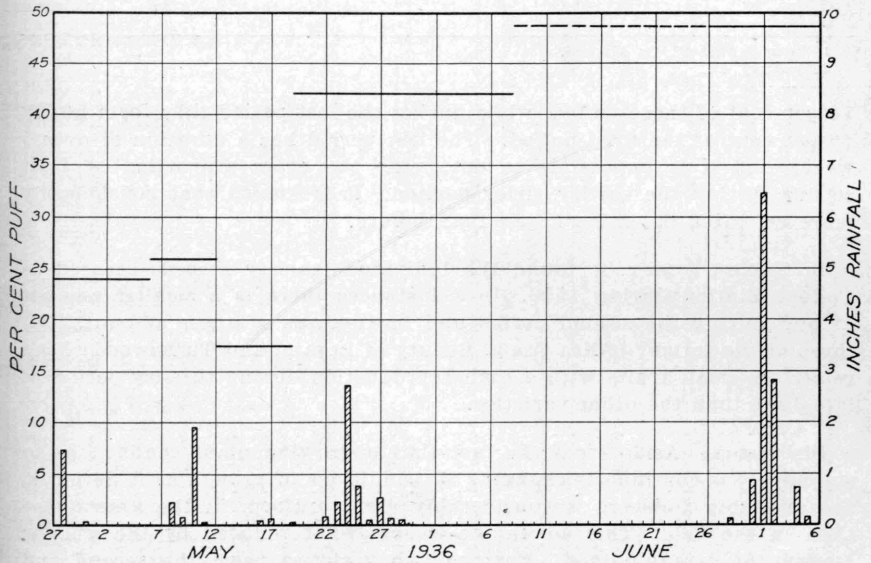

Figure 4. Per cent of puff among fruits set during periods indicated by horizontal lines, showing effect of rainfall at time of setting on per cent of puffed fruits. All varieties. College Station, 1936. Dotted line indicates few fruits set.

During the 1936 season at College Station several thousand flowers were tagged with the date of opening, and when examined the fruits were classified according to age. This permits a fairly exact examination of the effect of rainfall during the period the fruits were setting on the proportion of puff among these fruits when harvested. This comparison is made in Figure 4. Per cent of puff is represented by a straight line determined by the average of all lots for the period. Very few fruits were set during the latter part of June because of the high temperature and low humidity. This is indicated by the dotted line. In each case the proportion of puffed fruits is seen to be influenced by the soil moisture during the period of fruit setting.

The data on which Figure 4 is based are presented in Table 18. The proportion of severely puffed fruit seems to change more with a change in moisture conditions this season than that of those moderately puffed. In the period from May 13 to 19 the severely puffed fruit make up only

Table 18. Puffing compared with rainfall during fruit setting—College Station, 1936. Based on total fruit harvested—all varieties.

Date of fruit setting	Number of fruit			Per cent puff		Rainfall (inches)
	Normal	Moderate	Severe	Severe	Total	
Before May 7	538	133	42	5.9	24	2.75[1]
May 7 to 12	1172	331	99	6.2	26	2.50
May 13 to 19	2694	516	57	1.7	18	0.29
May 20 to June 8	2022	1160	317	9.1	42	5.09
After June 8	133	77	49	19	49	14.10[2]

[1]From April 21 to May 6.
[2]To July 16.

10 per cent of those puffed, while during the last period they form nearly 40 per cent of the total puffed. The last period has a duration of over 5 weeks and it is impossible to determine the exact proportion of fruit setting during the earlier, drier portion. It is known that considerably more set after the rains began than before.

In Table 19 may be found the individual variety records secured at College Station during 1936. In 3 instances there is a smaller amount of puff during the second period and in 10 cases a larger amount. All three of the former (Ailsa Craig, Beauty of Lorain, and Tuckswood) have relatively small fruits with a higher production during the dry period of late June than the other varieties.

Discussion: Aside from the fact that a growing plant confined as to soil supply is continually changing its conditions of growth as it develops, the available moisture is considerably more uniform in the greenhouse than in the field. This advantage is somewhat reduced by the smaller amount of data obtained. For the two varieties used, the second and third greenhouse experiments point definitely toward an increase in puff with increased available moisture during periods when high temperature is not the dominant factor.

Results from differential irrigations in the field are evidently complicated by a number of factors. When differences in available moisture in the field due to differential irrigation or periods of rainfall are considered, it is found that the different varieties and sometimes different strains of the same variety do not respond the same. Where a change in the amount

Table 19. Comparison of varieties and periods of fruit development, College Station, 1936. Based on total fruit for each period.

Variety	Lot No.	No. of fruits						Per cent puffed	
		Set April 21 to June 20			Set June 20 to July 16			First period	Second period
		Normal	Mod.	Severe	Normal	Mod.	Severe		
Ailsa Craig	515	68	14	10	33	0	0	26	0
Alice Roosevelt	516	45	3	0	18	8	1	6.2	.....
Beauty of Lorain	520	29	23	5	28	8	3	49	28
Blue Star Beauty	534	17	5	2	18	10	8	.....	50
Bonny Best	524	32	7	2	13	3	2	22	.....
Bonny Best	525	17	15	2	8	1	1	50	.....
Bonny Best	531	26	8	1	7	8	0	26	.....
Bonny Best	710	32	2	0	11	3	2	5.9	.....
Break O'Day	492	67	17	2	20	18	7	22	56
Break O'Day	536	27	7	1	8	8	1	23	.....
Canadian	540	47	10	1	10	1	0	19	.....
Chalk's Jewel	543	25	2	4	5	3	2	19	.....
Clark's Early	541	30	4	1	7	2	0	14	.....
Clark's Early	542	32	9	0	9	5	0	22	.....
Clark's Early	711	39	11	0	11	7	4	22	.....
Danish Early	548	93	8	6	24	10	17	13	53
Dwarf Early Red	555	16	13	33	8	5	10	74	.....
Earliana	440	44	4	0	5	1	0	8.3	.....
Earliana	453	24	8	3	1	2	0	31	.....
Earliana	557	36	12	2	2	5	0	28	.....
Early Detroit	560	15	2	1	18	12	6	.....	50
Early Texas Special	562	12	14	8	6	12	7	65	.....
Ficarazzi	563	34	5	0	8	9	1	13	.....
First Early	718	38	10	0	.....	.....	.....	21	.....
Globe	571	22	11	0	5	13	2	33	.....
Glovel	574	38	11	1	22	18	2	24	48
Greater Baltimore	576	26	8	1	5	3	1	74	.....
Grothen Globe	579	24	13	1	12	10	4	63	.....
John Baer	359	24	9	0	14	10	3	27	.....
John Baer	457	33	8	0	10	0	2	20	.....
John Baer	595	47	6	0	8	8	3	11	.....
Kanora	597	46	4	0	28	12	1	8	32
King Humbert	599	35	6	4	6	4	0	22	.....
Kondine	600	58	7	1	17	3	0	12	.....
Large Red	605	26	18	6	11	13	4	48	.....
Lucullus	611	35	7	0	41	8	1	17	18
Marglobe	434	502	195	25	272	357	51	30	60
Marglobe	624	26	12	0	20	10	0	32	33
Marglobe	625	19	11	3	21	13	1	42	40
Marglobe	626	29	10	2	8	7	0	29	.....
Marglobe	708	33	12	3	24	30	4	31	59
Marketeer	631	30	3	0	15	2	0	9.1	.....
McGee	635	50	19	1	9	4	0	29	.....
McGee	636	24	7	2	8	1	0	27	.....
New Orleans Market	639	33	4	0	6	8	1	11	.....
Pennsylvania State	644	48	18	0	18	12	1	27	42
Pritchard	646	20	5	0	25	18	2	.....	44
Pritchard	647	51	32	2	39	28	9	40	49
Queen of the Earliest	651	33	4	1	7	12	2	13	.....
Royal Purple	490	15	2	1	25	12	5	.....	40
Scarlet Dawn	508	15	15	1	10	5	2	52	.....
Stokesdale	709	28	10	0	8	7	0	26	.....
Stone	661	34	1	0	19	5	1	28	.....
Success	663	39	2	0	13	4	0	4.9	.....
Sunrise	497	64	19	1	21	7	1	24	.....
Sunrise	664	47	16	0	16	8	3	25	.....
The Trophy	666	56	7	7	15	11	7	20	55
Tuckswood	667	58	8	5	46	9	0	18	16
Westlandia	668	88	19	3	48	6	1	20	13

of puff occurs it is usually in the direction of the moisture change. Cooper's Special and Gulf State Market did not respond to differential irrigation treatments. Marglobe gave the greatest response; Chalk's Jewel, Pritchard, Scarlet Dawn, and Rutgers gave less.

Table 20 shows the behavior of varieties for which there are results for several lots over a period of years. In only 2 cases out of 110 was the response in a direction opposite what is expected—that is, less puff with

Table 20. Response to changes in rainfall—College Station, 1931-1936. Number of lots.

Variety	No change	Change as expected		Change opposite to expected
		Not significant	Significant	
Bonny Best	3	4	5	1
Break O'Day	1	1	6	1(?)
Cooper's Special	0	0	4	0
Dwarf Champion	1	3	5	0
Earliana	2	3	5	0
Early Detroit	1	2	3	0
Globe	1	1	5	0
Gulf State Market	1	1	11	0
John Baer	1	2	1	0
Marglobe	7	8	20	0
Total	18	25	65	2

more rainfall. Since the conditions under which these fruit set are known only approximately, it is possible that, if the exact moisture conditions were known, these results would fall into line. Lack of significance in the change may be due in some cases to small numbers of fruit.

A tendency was noted for certain lots both in the greenhouse and under irrigation in the field to show differences in puffing under differential treatment early in the fruiting period but not later. The development of the root system is no doubt a factor here, as perhaps are changes in structure of the stem and leaves.

Possibly the best evidence of a direct general relationship between the amount of available moisture and the amount of puffing comes from a comparison of results secured in the field over several periods. With the exception of the very hot 1934 season there was a general decrease in the amount of puffing with the advent of the drier part of the season. What is perhaps more important, during the season (1933) in which the wet and dry order was reversed there was a general increase in amount of puff. Further, the effective period has been found to be during setting and early development of the fruit. Evidence for this comes from both greenhouse and field.

The preliminary results with sprays and possibly the results with fertilizers, discussed later, give an indication that a number of factors influencing proportion of fruits puffed may be effective through their influence upon water conditions within the plant. Thus one group of factors, such as rainfall and irrigation, soil type, and temperature, seem to

exert an influence because of their effect on available soil moisture; another group, such as humidity, temperature, and sprays which have a bearing on rate of transpiration, may be effective in this way; and a third group, such as fertilizers which have an effect on the amount of plant colloids, may in this way affect water conditions within the plant. It is possible also that varietal differences may be of the latter type.

Only very brief mention of the work of the United States Department of Agriculture (1) along this line is yet available. On page 14 of the "Report of the Chief of the Bureau of Plant Industry, 1935" we find the following paragraph:

"Physiological studies have shown that one of the primary causes of puffiness in tomatoes is unfavorable water conditions, while other factors that may affect ovule fertilization also plays an important part. Maintenance of a uniform and adequate water supply and avoidance of low temperatures prevent the trouble in large measure."

While this indicates results somewhat different from those reported here, full agreement could hardly be expected where results vary so widely and conditions are difficult to control. Varietal or even strain differences could easily account for large discrepancies between results of independent workers. It is possible that there are one or more contributing factors that have not as yet been taken into account.

Temperature

The results secured in the greenhouse during the late spring of 1935 did not show a significant difference between plants growing in the tile under different moisture conditions. Those plants with a low "water table" had a slightly higher percentage of puff than those with a high water table. The data arranged according to harvest periods are presented in Table 21. It will be seen from Figure 5 that when these results are arranged according to time of setting the fruit, there is a general agreement in trend. First there is a reduction in the amount of puff, then an increase to about what it was before, then a second decrease, and finally a fairly consistent rise to 100 per cent or thereabouts.

Table 21. Differential water treatments—spring 1935. Based on total fruits each period.

Period	Ten-inch pots			Low water table			High water table		
	No. normal	No. puffed	Per cent puffed	No. normal	No. puffed	Per cent puffed	No. normal	No. puffed	Per cent puffed
May 9 – 15	.....	.....	.....	.....	.....	.....	5	22	82
" 16 – 20	6	11	65	10	14	58	6	37	86
" 21 – 25	8	2	20	2	14	88	14	21	60
" 26 – 31	13	2	13	9	48	84	13	46	78
June 1 – 5	5	11	69	8	26	77	15	40	73
" 6 – 10	4	8	67	4	37	90	12	16	57
" 11 – 15	1	6	86	2	18	90	9	17	65
" 16 – 20	2	7	78	1	31	97	1	43	98
" 21 – 27	0	3	100	0	6	100	0	16	100
" 30.....	4	20	83	0	16	100	4	54	93

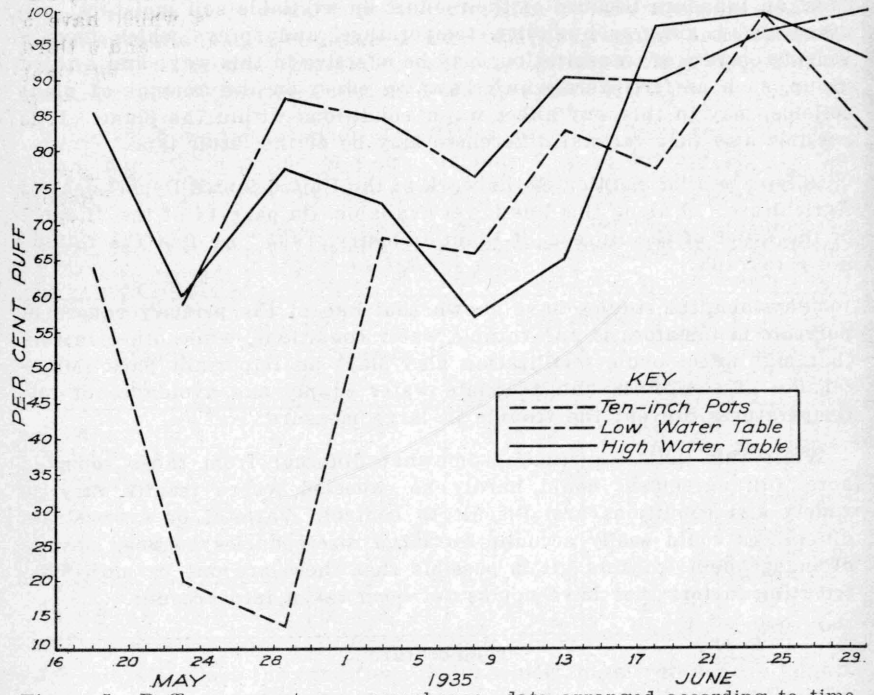

Figure 5. Puffing percentages, greenhouse—data arranged according to time fruit set.

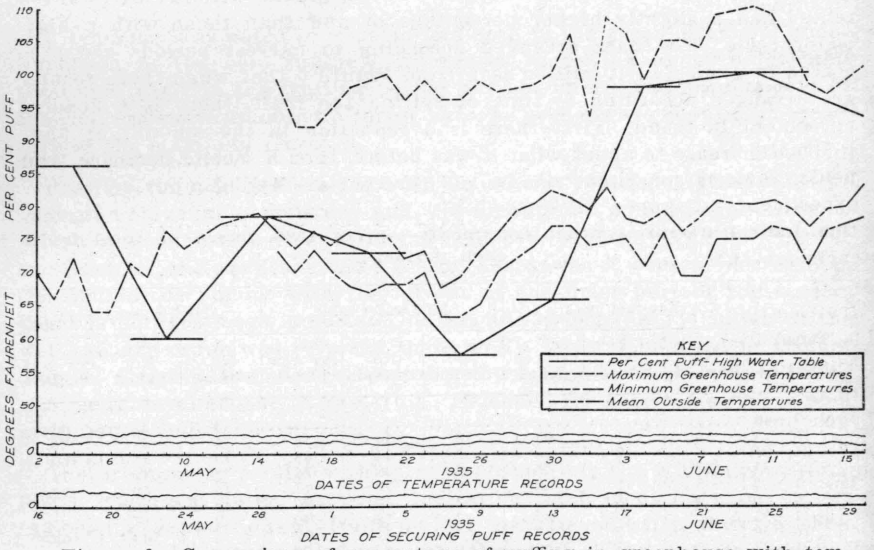

Figure 6. Comparison of percentage of puffing in greenhouse with temperatures at time fruit is setting. The horizontal lines represent the harvest period on which the per cent of puff is based.

When the results for the high water table lot are compared with daily maximum and minimum greenhouse temperatures and with the daily mean outside temperature at the time the fruit is setting (Figure 6), we find a similarity between the puffing curve and the minimum greenhouse and mean outside temperatures up to the point where the maximum greenhouse temperature exceeds 100°F. From May 7 to June 1 the correlation between the per cent of puff and mean outside temperature is .34. When the maximum greenhouse temperature exceeds 100° the percentage of puffed fruits rises immediately to 95 or more. As soon as the maximum temperature fell below 100° the percentage of puffed fruits decreased. The finely dotted portion of the maximum greenhouse temperature line represents an estimate based on the mean outside temperature for June 2.

Table 22. Temperature data for College Station

Temperature (degrees F.)	1931	1932	1933	1934	1935	1936
March (mean max.)	67.2	.....	.....	.....	.....	.....
(mean min.)	43.2	.....	.....	.....	.....	.....
(mean mean)	55.2	.....	.....	.....	.....	.....
April (mean max.)	75.0	81.3	81.2	81.2	79.1	80.7
(mean min.)	51.6	57.4	56.2	59.4	59.2	53.0
(mean mean)	63.3	69.3	68.7	70.3	69.2	66.8
May (mean max.)	82.7	86.1	89.8	87.6	83.0	83.4
(mean min.)	59.3	64.0	67.8	62.4	64.5	64.6
(mean mean)	71.0	75.1	78.8	74.9	73.8	74.0
June (mean max.)	94.6	92.3	93.2	98.3	90.0	95.0
(mean min.)	69.7	72.5	66.8	71.5	71.1	71.2
(mean mean)	82.2	82.4	80.0	84.9	80.6	83.1
July (mean max.)	96.2	98.5	96.2	100.8	94.3	91.2
(mean min.)	72.8	74.0	73.8	73.6	73.6	72.5
(mean mean)	84.5	86.3	85.0	87.2	84.0	81.9
August (mean max.)	96.2	96.6	95.1	98.6	96.9	96.0
(mean min.)	69.5	73.7	72.3	73.7	72.8	72.2
(mean mean)	82.9	85.2	83.7	86.2	84.9	84.1

Usually this drastic effect of high temperature is not obtained in the field. Temperature data for College Station covering the period of the experiments are to be found in Table 22. The mean maximum temperature for the entire month of July 1934 was 100.8°. From July 3 to 28 inclusive there were 13 days with a maximum temperature of 100° or over. The highest temperature (108°) was reached on July 24. While fruit setting was light during this period, the percentage of puff was high as compared with that of fruits set the following autumn (Table 15). This high proportion of puff during the summer is considered to be due to the high maximum temperatures at this time. No other season had such high maximum temperatures and for this reason high temperature rather than available water is considered to have been the dominant environmental factor.

There has been no opportunity to study unfavorably low temperatures. It is possible that the relatively low temperatures of March 1931 contributed to the puffing of the earliest fruits harvested that year.

Soil

Since the amount of available moisture is an important factor in determining the proportion of puffed fruits, different results may be expected from the same lot of tomatoes grown on different soils. In addition, other factors, such as differences in fertility, in organic matter, and in the available minor elements, may have an influence. The degree of effect of slight soil differences is important in a comparison between field grown plats differing with respect to some cultural treatment or genetic factor.

The replicated plantings of Marglobe made in 1935 serve as a measure of the variability due to soil heterogeneity at College Station (Table 16). Comparisons of replicated plats for the **same period** eliminate differences due to rainfall. The values of chi square presented in Table 23 are for

Table 23. Comparison of replications of Marglobe 434—College Station, 1935. (Data presented in Table 16.)

Lots compared	Values of chi square*	
	First picking	Second picking
2A- 8A	0.470	9.18
2A-14A	0.136	17.2
8A-14A	1.36	57.3
2A- 5B	3.94	0.72
2A- 8C	2.4	13.2
2A-11D	0.263	28.3
2A-14E	0.007	15.8
8A- 5B	1.24	4.71
8A- 8C	0.94	0.75
8A-11D	1.47	10.8
8A-14E	0.275	1.98
14A- 5B	5.14	30.1
14A- 8C	4.22	65.1
14A-11D	0.043	72.3
14A-14E	0.053	25.8
11B-14C	10.2	.....
11B-17D	2.03	.....
11B- 2E	4.93	.....
11B- 8E	3.88	.....
11B- 5F	0.005	.....
11B-11F	0.176	.....
17B- 2C	1.1	12.2
17B- 5D	0.067	0.20
2E- 8E	0.079	.....
2E- 5F	5.12	1.25
5F-11F	0.316	.....

* Values of 5 or more are considered significant.

the same period except in the case of 11B-14C, which gave a highly significant difference.

The plants were grown on Lufkin fine sandy loam. The A plats are ranged across one end of the field and the F plats across the other, with the rest arranged alphabetically between as previously described. The end of the field in which the F plats were located seems to be a little

heavier than the rest of the field. For the first picking there are only two cases in which the difference between plats is probably significant (14A-5B and 2E-5F). Since each of these pairs is in the same end of the field, and comparisons of similar plats do not show a significant difference, it is not thought that this represents a soil difference. The difference between 11B and 2E may be due to this factor.

When the second picking is considered, wide variations are found for two-thirds of the comparisons which have sufficient data. The heavy clay subsoil has a very definite undulating surface, causing the overlying sandy layer to vary from 5 or 6 inches to as much as a foot or more in depth. As the plants develop, available water supply would thus vary considerably between the replications and this is probably an important factor contributing to the differences observed later in the season.

The data for the replicated plantings at College Station have been discussed elsewhere (25). The percentages for these varieties—Albino, Kanora, and Marglobe—are included in Table 14, and the chi square calculations are given in Table 24. The tomatoes were grown on two pieces

Table 24. Comparison of replications—College Station, 1933.

Variety	Lot No.	Plats compared	Values of chi square*	
			June	July
Albino	194	3C–15	0.413	2.04
Kanora	26	16A–19	1.12	20.3
Marglobe	40	3C–12C	.....	0.152
Marglobe	40	3C–19C	.....	2.39
Marglobe	40	3C-19	.....	0.148
Marglobe	40	12C–19C	0.031	0.240
Marglobe	40	12C–19	1.67	1.28
Marglobe	40	19C–19	2.34	5.25

* Values of 5 or more are considered significant.

of ground about 4 rods apart that season (1933). The plats of one planting were both numbered and lettered; the others were given a number only. The harvests are grouped according to the month they were secured, the exact date not being recorded. There were no significant differences between replicated plats for the first picking. As in 1935, some of the plats, in this case 2 out of 8, had a significant difference later in the season. Calculations were not made for comparisons involving Marglobe plat 3C for the first picking because of small numbers of fruits.

Results of replicated plantings of Marglobe for the 1930 season at Weslaco are included in Table 43. Plants were grown in single row plats extending across the narrow way of a rectangular piece of ground. The plat number coincides with the row number, which gives an indication of distance between plats. The test was on Filigonio fine sandy loam soil. The comparisons for these plantings are given in Table 25. There is general agreement among the different plats. The two exceptions involve the middle and one border plat, one having significantly more, the other less, puff. The evidence from both locations indicates that where

Table 25. Comparison of Marglobe plantings—Weslaco, 1930.

Plats compared	Values of* chi square
1– 3	1.15
3– 9	1.14
3–11	0.053
3–13	1.80
3–15	5.67
3–17	2.76
3–19	0.058
3–21	1.56
3–23	0.578
3–25	0.0
3–27	4.62
9–11	0.707
9–21	0.02
9–27	1.22
23–25	0.578
23–27	8.14
25–27	4.62

* Values of 5 or more are considered significant.

the soil is reasonably uniform this is not likely to be an important factor for small areas, especially earlier in the harvest season. A restriction of comparisons to plats in adjoining rows would be expected to reduce later variability due to soil heterogeneity.

The possibility that the lack of puffing in the North might be due to some minor element in the glacial soils of that area led to a comparison of plants grown in pots in soil from Ann Arbor, Michigan, with plants grown in Texas soil. Five plants were grown in each soil in 10-inch pots in the greenhouse during the winter of 1935-36. While few fruits were obtained (Texas soil—5 normal and 11 puffed or 67%; Michigan soil—7 normal and 14 puffed, also 67%), it is evident that the soil obtained from Michigan does not contain a specific remedy for puffiness of tomatoes.

Fertilizers

At College Station, investigation of commercial fertilizers has been confined to a comparison of the effect on puffing in Marglobe and Norton of a 6-12-6 fertilizer at the rates of 300, 600, 1200, and 1800 pounds per acre. These treatments are available for comparison among themselves

Table 26. Effect of different amounts of 6-12-6 on proportion of fruits puffed—College Station.

Treatment (lbs. per acre)	Per cent puffed			
	1931[1]	1932[1]	1933[1]	1934[2]
None	33	77	52	58
300	31	72	41	38
600	27	60	35	47
1200	22	66	42	27
1800	23	66	44	46
Manure	..	..	..	38

1 Marglobe
2 Norton Wilt-resistant

Table 27. Comparison of fertilizer treatments—College Station. Based on total fruits for the season.

Rates compared	Year	Values of chi square*
None — 300	1931	0.522
None — 600	1931	5.36
None — 1200	1931	31.5
300 — 600	1931	2.72
600 — 1200	1931	7.33
1200 — 1800	1931	0.339
None — 300	1932	3.42
None — 600	1932	40.2
None — 1200	1932	34.7
300 — 1200	1932	2.18
None — 300	1933	23.6
None — 600	1933	42.7
None — 300	1934	2.99
None — Manure	1934	3.70

* Values of 5 or more are considered significant.

and with plats receiving no fertilizer (26). All plants were of the same age and were handled alike. Marglobe seedlings were used the first three seasons, Norton cuttings the last season. A manure treatment was added in 1934. The results secured over four seasons are presented in Table 26. In every instance the plants receiving fertilizer had less puff than those unfertilized. The difference between treated and untreated plats is not significant in every case when considered alone, but is always in the same direction. The values of chi square calculated for certain comparisons can be found in Table 27. The difference between plats receiving no fertilizer and those fertilized with 6-12-6 at the rate of 300 pounds per acre is significant only during 1933, but the difference between unfertilized plats and those fertilized at the 600 pound rate is significant each year except 1934, when the number of fruits is so small that no single difference is greater than that due to chance.

The proportion of puffed fruit has been determined for plats receiving a rather wide variety of fertilizer treatments at the Lower Rio Grande Valley Station for eight different seasons. These treatments are listed in Tables 28 to 32. Seven varieties were used at one time or another. Results for the first five seasons have been considered briefly by Friend (6). His conclusion that fertilizer applications do not affect the amount and degree of puffing under Lower Rio Grande Valley conditions is not modified by the additional data presented here. For certain years, less puff has been obtained with certain treatments than with no fertilizer, but the results are not consistent. A comparison of results with the same variety on successive years discloses as great inconsistency as where different varieties have been used.

When plats receiving nitrogen in some form are compared with those receiving no nitrogen, similar inconsistencies are observed. During 1926 nine plats receiving nitrogen averaged 59.6 per cent puff while six plats receiving no nitrogen in the treatment averaged 62.3 per cent. An average of the five seasons where the treatments were repeated (Table 29) gives

Table 28. Effect of fertilizers on puffing of Globe—Weslaco, spring 1926. Based on 100 fruits per plat.

Plat No.	Treatment	Rate per acre (lbs.)	Per cent puff
1	None	.....	60
7	None	.....	52
14	None	.....	84
15	None	.....	60
	Average	.....	64
6	Acid phosphate	300	76
5	Acid phosphate	300	
	Muriate of potash	60	42
3	Sulfate of ammonia	50	36
4	Sulfate of ammonia	50	
	Acid phosphate	300	56
10	Cotton seed meal	150	
	Acid phosphate	300	60
8	Sulfate of ammonia	50	
	Muriate of potash	60	84
9	Kainit	250	52
11	Sulfate of ammonia	85	
	Acid phosphate	300	
	Sulfate of potash	52	72
12	Sulfate of ammonia	85	
	Acid phosphate	300	
	Muriate of potash	52	60
	Average	.....	66
13	Cotton seed meal	100	
	Sulfate of ammonia	25	
	Acid phosphate	300	
	Muriate of potash	60	68
2	Barnyard manure	20,000	48

29.8 per cent where nitrogen was applied and 31.5 per cent for the plats receiving no nitrogen. In both cases there appears to have been an improvement where a nitrogen carrying fertilizer was used. However, during 1934 plats fertilized with 11-48-0 at the rate of 300 pounds per acre had 64.2 per cent puff compared with 62.7 for the unfertilized plats. During 1936 the plats receiving nitrogen averaged 26.1 per cent against 16.7 per cent for those receiving none. The high amount of puff found among the plats receiving nitrogen alone this year may possibly be accounted for by their position in the field. It will be noted from Table 32 that the other treatments have much less puff and are fairly uniform in this respect. When the four treatments of each replication are averaged we have (following the field arrangement of plats) 14%, 10.5%, 16%, 28%, and for the three forms of nitrogen 49%. Thus when differential treatments are disregarded, excepting the last, there is a consistent increase in the amount of puff for each of three succeeding replications culminating in the high percentages of the nitrogen treatments. Since these latter were not replicated, there is no way of separating the effect due to position in the field from an effect due to the treatments. The lack of correspondence between these results and those secured during pre-

Table 29. Effect of fertilizer applications, Weslaco 1927-29 and 1931-32.
Percentages of puff based on total fruit or on large samples.

Treatment	Rate per A (pounds)	1927[1]			1928[2]				1929[2]		1931[3]			1932[3]			Average
		June 6	June 20	Av.	May 23	June 11	June 20	Av.	June 21	Av.	June 19	June 26	Av.	May 27	June 6	Av.	
None	.....	..	28	..	19	24	29	..	40	..	37	12	..	54	36	..	..
None	.....	14	4	..	..	15	21	..	40	..	32	30	..	38	40	..	..
None	.....	22	56	25	12	13	26	20	42	41	10	22	22	57	46	45	31
0 - 8 - 0	600	46	40	..	14	13	25	..	43	..	53	20	..	43	34	..	..
0 - 8 - 0	600	6	24	29	18	12	22	17	32	38	45	17	31	53	49	45	32
4 - 8 - 0	600	36	8	..	6	12	19	..	43	..	47	18	..	53	39	..	..
4 - 8 - 0	600	4	28	19	3	21	19	13	42	43	39	17	30	53	51	49	31
4 - 8 - 4	600	12	20	..	3	21	16	..	41	..	38	10	..	51	35	..	..
4 - 8 - 4	600	12	16	15	27	14	21	17	45	43	38	18	26	57	45	47	30
4 - 8 - 8	600	22	8	..	21	14	28	..	41	..	40	28	..	49	38	..	..
4 - 8 - 8	600	27	12	17	13	19	39	22	41	41	31	25	31	49	38	44	31
4 - 8 - 8	1,200	7	20	14	24	13	19	19	37	37	15	15	15	57	42	49	27
Manure	40,000	11	24	..	12	15	28	..	43	..	48	18	..	42	35	..	..
Manure	40,000	20	19	19	6	16	23	17	42	43	30	12	27	54	37	42	30

1 Globe
2 Cooper's Special
3 Break O'Day

Table 30. Comparison of fertilized and unfertilized plats of Marglobe—Weslaco, fall 1934. Based on total harvestable fruit at each picking, the last picking including all fruits of any size.

Treatment Date of Harvest	No. normal	No. puffed	Per cent puffed
11 - 48 - 0 300 lbs per A.			
November 26	4	20	83
December 8	34	24	41
December 26	199	422	68
Average			64
Not fertilized			
November 26	9	46	84
December 8	36	52	59
December 26	307	336	45
Average			63

Table 31. Effect of fertilizers—Weslaco, fall 1935. Based on total fruit each picking.

Variety	Treatment	October 28			November 4			Per cent puff	
		No. fruits			No. fruits				
		Normal	Mod.	Severe	Normal	Mod.	Severe	Oct.	Nov.
Clark's Early	Fertilized*	83	10	2	92	7	1	3	8.0
Clark's Early	None	45	2	1	82	2	0	6.3	2.4
Purple Pritchard	Fertilized*	49	11	16	198	67	23	36	31
Purple Pritchard	None	42	14	13	235	55	37	39	28

*Each plant fertilized with five ounces of 32% superphosphate applied October 7.

Table 32. Effect of fertilizers (Stokesdale), Weslaco, spring 1936. Based on 100 fruit samples per plat.

Treatment	Rate per A (pounds)	Per cent puff			
		Moderate	Severe	Total	Average
None	...	6	6	12	
None	...	7	3	10	
None	...	7	2	9	
None	...	18	17	35	16.5
0 - 18 - 0	600	11	3	14	
0 - 18 - 0	600	6	1	7	
0 - 18 - 0	600	20	3	23	
0 - 18 - 0	600	7	16	23	16.8
6 - 18 - 0	400	12	1	13	
6 - 18 - 0	400	12	3	15	
6 - 18 - 0	400	13	1	14	
6 - 18 - 0	400	19	6	25	16.8
6 - 18 - 0	600	11	7	18	
6 - 18 - 0	600	9	1	10	
6 - 18 - 0	600	16	2	18	
6 - 18 - 0	600	16	12	28	18.5
Sulfate of ammonia	400	18	21	39	39
Nitrate of soda	500	33	23	56	56
Cyanamid	400	35	16	51	51

vious years, together with the obvious trend toward increased puffing in this end of the field, indicate that this wide difference is not primarily due to the nitrogen carriers applied to the last three plats.

The application of phosphate alone may have increased the amount of puffing in Clark's Early during 1935 and possibly in Globe during 1936, but it had no effect on Purple Pritchard, on Stokesdale, or on the varieties listed in Table 29.

Supplements: During the 1932 season, the guard rows of each of the fourteen fertilizer plats at the Weslaco station were treated with sulphates of manganese and iron, applied about the plants at the time of the final thinning. The plants in the first row of each plat received iron sulphate at the rate of fifty pounds per acre, while the fourth row in each plat received a similar application of manganese sulphate. Results of the test with these materials are presented in Table 33. Plants which receive the iron sulphate supplement produced slightly less puffy fruit than the untreated plants, and this also held true for the plants that received manganese sulphate. However, the differences were not found to be significant, as the chi square values for the two periods of the test were 0.889 and 0.172, respectively.

Table 33. Effect of manganese and iron supplements on puffing of Break O'Day—Weslaco, spring 1932.

Treatment	Rate per A.	May 27			June 6		
		No. normal	No. puffed	Per cent puffed	No. normal	No. puffed	Per cent puffed
None	..	305	310	50	562	378	40
$FeSO_4$	50	225	250	52	608	442	42
$MgSO_4$	50	313	310	50	567	373	40

Discussion: The lack of agreement between the results secured at College Station and at Weslaco can most readily be explained by differences in soil type and soil fertility between the two locations. The Lufkin fine sandy loam on the Main Station horticulture farm has a shallow surface layer and is lacking in natural fertility. Crops respond well to applications of commercial fertilizer on this soil. In contrast, the deep alluvial soil types of Substation No. 15 are somewhat heavier and vastly more fertile. The application of commercial fertilizers under these conditions would not be expected to have the same effect as at College Station.

In the work of Sando (14) previously referred to, seven different fertilizer ratios were applied to plats of the Globe variety. The nitrogen varied from 1 to 7 per cent, the phosphoric acid from 5 to 10 per cent, and the potash from 0 to 8 per cent. All plats contained some puff. The author says that "complete counts could not be made, owing to the destruction of vines by a flood before the end of the season, but enough observations were made to show that within the limits used varying quantities of fertilizer elements did not influence the production of hol-

low fruit." No data are presented. It seems possible that had sufficient data been collected, a significant difference might have been found between fertilized and unfertilized plants.

The work of Crist (3) shows that the application of fertilizers to soil deficient in this respect has a decided influence on the water content of tomato plants. Applications of nitrogen, phosphorus, and potassium carriers increased the proportion of water in the tops slightly and increased the per cent of bound water much more. They also reduced the rate of drying of the tops after being cut off. If the expression of puffing were greatly influenced by the amount of free water within the plant during a relatively brief period in its early development, it is conceivable that the observed decrease of puff with the use of fertilizer at College Station was influenced by an increase in the proportion of bound water in these plants. It is also possible that this may have a bearing on the varietal and strain differences observed. However, the author just cited considers that "the concept of bound water as an explanation of increased water content, decreased rates of transpiration and dehydration, increased hardiness, etc., in plants appears to be more or less unsatisfactory." Fertilizers might influence the amount of puffing by their effect on such things as cell permeability and structure of tissues. That fertilizers have been shown to influence a factor directly affecting amount of puffing would seem to be a step in reaching an explanation of a character which is highly complicated in its expression.

Disease

Southern Blight: An important result of continuous cropping on the same land year after year is the accumulation of disease organisms. Since one aspect of the work at College Station is the development of desirable strains, plants have been grown on the same piece of ground three years in succession in order that disease-resistant types might be selected. Only one disease—southern blight, caused by *Sclerotium rolfsii*—was at all prevalent. The possibility that the amount of puffing might be changed because of the activity of this parasite was investigated by comparing

Table 34. Comparison of fruit from normal and diseased plants, College Station, 1935. Based on total fruit at first harvest.

Variety	Condition of plants	No. plants	No. fruits		Value of* chi square
			Normal	Puffed	
Dwarf Champion 350	Normal	15	119	46	
	Diseased	10	76	17	2.97
Kanora 366	Normal	15	228	29	
	Diseased	10	85	14	2.55
Marglobe 434	Normal	14	82	57	
	Diseased	9	42	43	1.95
Matchum 266	Normal	4	43	8	
	Diseased	8	68	22	1.49

* Values of 5 or more are considered significant.

results for diseased and normal plants of four varieties (Table 34). In no case was the difference significant. In cases where the plant was seen to be dying, all fruits which were large enough were examined. The proportion of fruit set before and after the plant became diseased are not known. It is possible that a comparison of these groups would show a significant difference. Friend (7) found a larger amount of puffing "where a larger number of the plants showed marked evidence of decline toward the end of the season."

Blossom End Rot: During the course of the greenhouse experiments in the spring of 1935 considerable blossom end rot was observed after June 6. Nearly 34 per cent of the fruits secured from the low water table lot after this date were affected, while only 7 per cent of the fruits from the high water table lot had the disease during the same period. When per cent of puff for all fruits is considered, a higher proportion of fruit from the low water table has puff than does that of the other group. The proportion of puffed fruits among those affected with blossom end rot is about the same as for all fruits in each water treatment (92 and 94 per cent in one case and 85 and 92 per cent in the other). Since this is true and the proportion of puffed fruits in both lots is high, there does not appear to be a close relationship between the two.

Pollination

Most of the work done elsewhere on pollination has been on greenhouse tomatoes. This has been reviewed by Schneck (15) in his report on methods of pollination. A point of interest in this and other publications has been the abnormal development of the fruit resulting from inadequate pollination. On page 38 of his report Figure 20 illustrates abnormal development of a Bonny Best fruit which had been unpollinated. One seed locule is fairly well developed. The others have been nearly filled by the over-grown cross walls which make a fairly solid fruit. This would be classed as a puffed fruit in our work, but it is not typical. Bailey (2) illustrates a similar condition, although not so pronounced. An uncut fruit poorly developed on one side is also illustrated. Such a condition is unusual among puffed fruits. Munson's illustrations (11) are similar to Bailey's. Fletcher and Gregg (5) used different amounts of pollen—an excess, a small amount, and only a few grains. Fruits resulting from the use of a large amount of pollen were normal. Fruits developing after pollination with a small amount of pollen were much smaller and gave evidence of what would be classified as a moderate degree of puff, judging from the illustration. Fruits resulting from the application of only a few pollen grains also were small and contained very few seeds. While it is difficult to judge from the figure, these last fruits obviously do not exhibit typical puffing, although there is indeed a marked similarity to this condition. White (23) contrasts photographs of an unpollinated cluster of Carter Sunrise with one resulting from hand pollination. Fruits of the former are angular and have the external appearance of those puffed.

All of the flowers on 25 plants of Marglobe 434 grown in the field at College Station were hand pollinated during the first period of the 1935

season. Pollination was effected by picking off the stamens of open flowers and transferring the pollen to the stigma by means of a pair of forceps. The puffing record is compared with that of 25 similar plants from the same lot in Table 35. During this first period the fruits resulting from hand pollination had significantly less puff than those unpollinated. During the second period when neither was pollinated the check had slightly less puff but the difference was not significant.

Table 35. Effect of hand pollination on puffing in the field (Marglobe), College Station, 1935. Based on total harvestable fruit for each period.

Treatment	First period			Second period		
	No. normal	No. puffed	Per cent puffed	No. normal	No. puffed	Per cent puffed
Hand pollinated first period only...	96	173	64	295	102	27
Hand pollinated neither period.....	62	180	74	267	86	24
Chi square.....	.....	6.08	.....	.....	0.176	

This evidence on the influence of pollination on puffing of the fruit is supported by other observations. The cumulative evidence from both greenhouse and field of a critical period about the time the fruit is setting favors an effect from pollination and, presumably, opportunity for fertilization. The observed effect of high temperature on the proportion of fruits puffed may be through its influence on pollen tube growth. Smith and Cochran (16) found that the percentage of tomato pollen grains germinating at 100°F. ranges from 0.1 to 6.3. Eighty-four hours after pollination no tube had grown more than 2 mm. in length at this temperature. Since maximum greenhouse temperatures sometimes exceeded 110°F., it seems likely that damage to the pollen by heat may have been the dominant factor in the 100 per cent puffing observed during this period.

It hardly seems possible that the effect of the various hereditary and environmental factors is limited to their influence upon pollen tube growth and subsequent fertilization of the egg. There are several reasons for thinking this. Attention has been called to the appearance of fruits known to be "puffed" from lack of adequate pollination. This is not typical of ordinary puffing. While fruits that are puffed the worst usually have no normal seeds, many fruits puffed rather badly appear to have a full complement of seeds. On the other hand, fruits with little or no puff have been observed without a sign of seed development. The final conclusion will depend to some extent on the exact definition of puffing used.

Position of Fruit

At the time the puffing data obtained in the greenhouse during the spring of 1935 were recorded, the cluster from which the fruit was obtained was noted. These data can be found in Table 36 with comparisons in Table 37. There is a marked and consistent rise in percentage

of puff from the first to the last clusters for plants in pots and for those with a low water table. This difference is not significant for the first three clusters, probably because of small amount of data. For the high water table lot the only significant difference is between the first and fifth clusters.

Table 36. Position of fruit on the plant—spring 1935. Based on total fruits per cluster.

Treatment	Cluster	No. normal	No. puffed	Per cent puffed	Av. height (in.)
10-inch pots	1	23	22	49	23
	2	12	17	59	30
	3	7	16	70	38
	4	1	14	93	45
Low water table	1	14	42	75	20
	2	12	49	80	30
	3	9	54	86	40
	4	1	44	98	49
	5	0	20	100	67
High water table	1	23	75	77	21
	2	22	82	79	30
	3	17	68	78	39
	4	15	54	78	46
	5	1	30	97	54

In comparing the same clusters of different lots no difference is found between the first clusters of the low and high water table lots, but there is a significant difference between the fourth clusters of these two lots. This is to be expected since the first and fourth clusters of the high water table are about the same while these clusters of the low water table are different. The fifth clusters of both lots differ very little. The significant increase has thus occurred between the third and fourth clusters of the low water table lot and between the fourth and fifth clusters of the lot

Table 37. Comparison of different clusters within and between lots.

Groups compared				Values of* chi square
Treatment	Cluster	Treatment	Cluster	
10-inch pots	1	10-inch pots	2	0.67
10-inch pots	1	10-inch pots	3	2.63
10-inch pots	1	10-inch pots	4	9.25
Low water table	1	Low water table	2	0.47
Low water table	1	Low water table	3	2.18
Low water table	1	Low water table	4	10.2
Low water table	1	Low water table	5	6.12
High water table	1	High water table	2	0.15
High water table	1	High water table	3	0.32
High water table	1	High water table	4	0.068
High water table	1	High water table	5	6.37
Low water table	1	High water table	1	0.045
Low water table	4	High water table	4	8.59
Low water table	4	10-inch pots	4	0.68
Low water table	5	High water table	5	0.65

* Values of 5 or more are considered significant.

with the high water table. The fourth cluster of the low water table and the fifth cluster of the high water table were setting at about the same time and therefore under similar environmental conditions (see discussion under temperature).

A difficulty in comparing fruit from clusters on the same and different plants lies in the fact that the periods of fruit setting may overlap yet do not ordinarily coincide. This means that, among clusters, the fruits usually set and develop under somewhat different environmental conditions and for this reason differences in amount of puff cannot be assigned to position on the plant. While this may be an important environmental factor, it can not, under these conditions, be distinguished from other factors.

Hereditary Factors

With such ready response to environmental conditions, it is essential to make comparisons only when the lots being compared are grown under very similar conditions. Further, puffing results should be compared only where the fruits have developed over approximately the same period. This has been discussed in connection with replicated plantings of Marglobe 434 grown at College Station during the 1935 season. When a comparison is made within these limits identical lots have been found to vary no more during the first part of the fruiting season than would be expected on a basis of chance sampling. Where a significant difference is found between lots for the same period, grown under comparable conditions, the possibility that such difference may have a genetic basis presents itself. It does not necessarily follow that a difference obtained under such conditions is always genetic, as is amply illustrated by the variation between lots of Marglobe 434 during the second period (Table 16), but there is excellent reason to believe that important genetic differences exist among many varieties and sometimes among strains of the same variety. The evidence for this has to do with the range in amount of puffing of varieties, strains, and replications, with the consistency of varietal differences, with a comparison of individual plant selections within a variety, and finally with the results of intervarietal crosses.

Varieties and strains: Varietal differences have been discussed in previous publications (6, 25). This work is presented here in somewhat greater detail and later results are added. Some attention has been called to varieties in the discussion of change in amount of puffing with advance in the season (Tables 12 to 19). In general the Globe and the very large fruited types, such as Beefsteak, have considerably more puff than varieties of the Bonny Best type. The small-fruited tomatoes, with the exception of Pomodora, have very little puff. Because of the commercial importance of the variety, the uniformly large amount of puffing found in Marglobe is of interest. Globe, one of its parents, also has a consistently high amount of puff.

Within the limits of sampling error the percentage of puff should be the result of the interaction of genetic and environmental factors, external and internal, the latter environmental factors conditioned in part by

the former. Under comparable environmental conditions greater differences would be expected, on the whole, between varieties than between strains, and likewise greater differences between strains and selections than between replicated plantings having in the aggregate the same heredity. During the 1932 season at College Station the range in variation for 55 varieties and strains for the June picking was from 18

Table 38. Range in percentage of puffing of different lots of the same variety, College Station 1932.

No. lots	Variety	June			July		
		Lowest	Highest	Range	Lowest	Highest	Range
4	Bonny Best	29	52	23	15	42	27
4	Break O'Day	49	52	3	26	34	8
4	Earliana	18	57	39	10	27	17
4	Globe	36	77	41	32	57	25
4	Gulf State Market	24	52	28	13	34	21
11	Marglobe	55	83	28	57	79	22
55	All Varieties	18	83	65	8	79	71

(Earliana 12) to 83 per cent (Marglobe 41), and for July from 8.4 (Acme 67) to 79 per cent (Marglobe 11). The range for different lots of six variations is given in Table 38. The range for all varieties during June 1932 is 65 points. The greatest range for any variety at this harvest is 41 points for Globe. For July the range for all varieties is somewhat greater—71 points; the greatest range for any single variety is 27 for Bonny Best. If the 11 lots of Marglobe were a representative sample of the 55 lots including all varieties tested that year, and the amount of puffing were due entirely to environmental factors without respect to genetic differences, the range of variation of these 11 lots would be expected to approach that of the entire group. This is obviously not the case. No lot of Marglobe has less than 55 per cent puff at the June harvest, a figure much higher than the 18 per cent of Earliana and approximating the upper limit for that variety. For the July harvest there is an even greater discrepancy between the lowest lot of Marglobe (57%) and the lowest lot of all (Acme, 8.4%). Considering the highest strain of each of the three varieties (Bonny Best, Break O'Day, and Gulf State Market, involving a total of 12 lots) not one comes within 30 points of the lot with the greatest amount of puff (a strain of Marglobe) for either June or July (Table 38).

Results for the two harvest periods are fairly consistent. Without exception, the lot with the lowest amount of puff at the June picking was also the lowest for the variety at the second harvest. The highest lot was the same for the two periods in four of the six varieties; one of the exceptions was Marglobe. This consistency might, with reason, be assigned to either environmental or genetic factors primarily. However, the genetic complement can not have changed materially, while certain phases of the environment are known to have changed.

Another point of evidence in favor of the importance of genetic factors is the difference in variation among the different lots of the varieties listed. Marglobe with 11 lots had a much smaller range at the first picking than Earliana and Globe with only 4 lots each, and about the same as Gulf State Market. At the second picking its range was less than that of either Bonny Best or Globe. The four lots of Break O'Day have a very small total range at each picking. In an earlier paper (25) it was concluded that the four lots of Break O'Day represent no more than two slightly different strains, while the four lots of Globe represent three distinct strains. This leads to the conclusion that the thing that prevents the lots of one variety from varying more than might be expected on a basis of chance is genetic similarity, and where lots of one variety do vary widely under similar environmental conditions much wider genetic differences with respect to puffing exist. Consistency of behavior of replicated plantings over the same period has already been noted.

In a consideration of results secured over a period of years, marked changes in environmental factors must be taken into consideration. Bonny Best, Dwarf Champion, Early Detroit, and Gulf State Market as grown at College Station will be discussed from this standpoint. Plantings of the same lot made during different seasons will be considered first. Inasmuch as the same variety did not occupy precisely the same position each year, soil variation may have been a factor contributing to the degree of variability. Bonny Best 33 and 39 were grown both in 1932 and in 1933 (Tables 13 and 14). Both lots had less puff the second year. No. 33 had considerably more puff than No. 39 the first season, but slightly less the second. The hereditary factors remained the same, yet the difference between the two seasons seemed to have greater effect on No. 33 than on No. 39. Since No. 33 had more puff in 1932, the same relationship might be expected with a change in environmental conditions. Two or three explanations appear promising. If, say, five per cent were the irreducible minimum for the variety, one would expect little or no difference between the two strains when conditions were highly favorable for normal fruit development, but a rather wide difference might be possible when conditions favored a large amount of puff. As a second consideration it seems likely that the change in environmental conditions was not precisely the same for both lots. A third point is the probability that each genetic type responds perhaps in a different way or at least at a different rate from another genotype with any specific change in the environment. For example strain A might have 30 per cent puff under one set of moisture conditions and 60 per cent under another, while strain B might have 30 per cent puff under the first and only 45 per cent under the second. Incidentally it is not known that the fruits of these strains of Bonny Best set in the same proportions over exactly the same period.

Gulf State Market 10 and 32 were grown both in 1932 and in 1933. In this instance No. 10 had less puff than No. 32 in 1932 but a similar low amount for the first picking of 1933. The situation thus far is similar

Table 39. Comparison of varieties—Weslaco, spring 1926. Based on 25 fruits per picking.

Variety	Row No.	Per cent puffed	
		June 4	June 15
A and M First Early	6	0	0
Acme	35	0	8
Acme	54	0	2
Avon Early	16	0	0
Avon Early	45	0	0
Beauty	27	0	20
Brimmer	49	0	0
Burbank Early	19	0	0
Burbank Early	48	0	0
Cooper's Special	17	60	48
Cooper's Special	46	80	60
Coreless	11	80	80
Coreless	39	70	16
Earliana	21	0	0
Early Detroit	18	30	20
Early Detroit	47	0	12
Early Michigan	23	0	0
Fordhook First Early	34	0	0
Globe[1]	51	80	40
Globe[1]	56	60	72
Globe[2]	53	80	40
Globe[3]	2	80	68
Globe[3]	10	80	52
Globe[3]	20	80	72
Globe[3]	30	84	68
Globe[3]	40	80	72
Globe[3]	50	80	76
Globe[3]	58	60	48
Globe[3]	59	60	72
Gulf State Market[2]	4	20	60
Gulf State Market[3]	8	60	28
Gulf State Market[3]	37	40	32
Hummer	24	0	64
June Pink	5	0	4
June Pink	15	20	4
June Pink	44	0	0
June Pink	3	40	28
John Baer	32	0	0
John Baer	52	0	8
John Baer	57	20	8
Manyfold	31	0	8
Matchless	33	0	12
Norduke	22	60	44
Norton	29	0	36
Paragon	7	60	28
Perfect First Early	14	0	4
Perfect First Early	43	0	20
Perfection	28	20	0
Rosy Morn	11	80	80
Rosy Morn	39	70	16
Red Field Beauty	12	40	8
Red Field Beauty	41	0	8
Red Head	13	60	16
Red Head	42	40	36
Self Pruning	36	90	20
Trucker's Favorite	25	0	44

[1]From Burpee. [2]From Ferry. [3]From Livingston.

Table 40. Comparison of varieties—Weslaco, spring 1927. Based on total fruits for first two pickings; 25 fruit sample at third picking.

Variety*	Row No.	June 7		June 14		June 22		Per cent puffed		
		No. fruit		No. fruit		No. fruit				
		Normal	Puffed	Normal	Puffed	Normal	Puffed	7	14	22
Acme	34	5	0	31	0	25	0	.....	.....	.....
Beauty	28	11	3	34	1	23	2	.....	.....	8
Beauty	29	4	0	14	0	25	0	.....	.....	.....
Beauty	31	1	0	12	0	22	3	.....	.....	12
Beauty	32	5	1	41	0	24	1	.....	.....	4
Beauty	23	3	0	47	0	23	2	.....	.....	8
Burbank Early	48	168	11	191	15	24	1	6.1	7.3	4
Cooper's Special	17	13	4	23	7	22	3	24	23	12
Cooper's Special	18	35	16	122	21	23	2	31	15	8
Cooper's Special	19	46	17	170	55	22	3	27	24	12
Cooper's Special	21	57	15	148	30	23	2	21	17	8
Cooper's Special	22	27	12	58	12	21	4	31	17	16
Duke of York	49	6	0	24	0	24	1	.....	.....	4
Duke of York	51	.....	.....	3	0	0	4	.....	.....	.....
Dwarf Champion Early	57	50	1	55	1	25	0	1.9	1.8	.....
Dwarf Giant	58	.....	.....	3	0	0	2	.....	.....	.....
Early Detroit	35	5	0	5	3	25	0	.....	.....	.....
Early Detroit	36	11	0	17	5	22	3	.....	23	12
Fordhook Flint	45	27	0	123	0	23	2	.....	.....	8
Globe	1	7	5	14	10	4	21	.....	42	84
Globe	2	4	2	17	10	13	12	.....	37	48
Globe	10	3	3	24	11	18	7	.....	31	28
Globe	20	8	2	28	9	21	4	.....	24	16
Globe	30	14	10	47	16	20	5	42	25	20
Globe	40	2	0	14	5	17	8	.....	26	32
Globe	50	.....	.....	10	2	18	7	.....	.....	28
Globe	59	2	2	1	1	21	4	.....	.....	8
Globe	60	2	0	6	3	12	13	.....	.....	52
Globe	12	5	2	0	0	20	5	.....	.....	20
Globe	13	7	4	0	1	7	3	.....	.....	.....
Globe	14	4	0	0	9	19	6	.....	.....	24
Globe	15	2	1	0	4	18	7	.....	.....	28
Globe	16	4	1	0	6	12	13	.....	.....	62
Gulf State Mkt.	25	58	6	65	11	22	3	9.4	15	12
Gulf State Mkt.	26	60	12	51	10	25	0	17	16	.....
Gulf State Mkt.	27	50	10	67	8	22	3	17	11	12
June Pink	3	151	2	100	8	24	1	1.3	7.4	4
June Pink	4	128	2	53	4	23	2	1.5	7.0	8
June Pink	5	94	8	67	1	11	6	7.8	1.5	.....
June Pink	6	99	6	85	6	24	1	5.7	6.6	4
June Pink	7	187	13	84	11	21	4	6.5	12	16
Kanora	47	5	2	23	10	17	8	.....	30	32
Long Keeper	42	7	2	88	0	24	1	.....	.....	4
Louisiana Pink	8	30	17	103	44	20	5	36	30	20
Louisiana Pink	9	42	25	30	11	18	17	37	27	68
Louisiana Pink	11	32	13	28	16	16	9	29	36	36
Louisiana Red	55	44	23	132	51	18	7	34	28	28
Magnus	37	2	1	4	2	21	4	.....	.....	16
Marglobe	52	21	6	21	12	10	15	22	36	60
Marglobe	53	10	4	26	15	12	13	29	37	52
Marvelosa	43	18	3	58	1	25	0	14	1.7	.....

*Each row of the same variety represents a different seed source except Globe rows 1, 2, 10, 20, 30, 40, 50, 59 and 60.

Table 40. Comparison of varieties—Weslaco, spring 1927. Based on total fruits for first two pickings; 25 fruit sample at third picking.—Continued

Variety*	Row No.	June 7		June 14		June 22		Per cent puffed		
		No. fruit		No. fruit		No. fruit				
		Normal	Puffed	Normal	Puffed	Normal	Puffed	7	14	22
Mikado.....	46	7	2	15	1	21	4	.....	6.3	16
Perfect First Early.....	56	84	11	114	20	24	1	12	15	4
Rosy Morn.....	44	16	6	28	2	18	7	27	6.7	28
Self Pruner.....	23	62	13	150	39	25	0	17	21	.....
Self Topper.....	24	33	6	107	27	25	0	15	20	.....
Trucker's Favorite	39	1	2	5	1	18	7	.....	.....	28
	41	.....	.....	5	1	20	5	.....	.....	20

*Each row of the same variety represents a different seed source except Globe rows 1, 2, 10, 20, 30, 40, 50, 59 and 60.

to that of Bonny Best. At the second picking No. 10 had about 10 points more puff than No. 32. The third point mentioned above may be the explanation for this behavior.

Results of tests of varieties secured at College Station and at the Lower Rio Grande Valley Station (Tables 39 to 46) have been fairly consistent. Close correspondence could not be expected because of difference in growing conditions which may easily be greater during the same season than between two seasons at either location, because the strains under test were not always identical, and because the error due to small samples was sometimes rather large at one or both points. The high percentage of puff in Marglobe has been evident at both places. A few varieties such as Acme and John Baer, June Pink, and certain strains of Earliana and Gulf State Market have given comparatively low percentages at both places. While this bulletin is concerned chiefly with the role of variety as a factor in determining the amount of puffing, all available puffing data on varieties have been given and so can be considered in an estimate of the commercial desirability of any variety. All data appear in tables except the varietal results at Weslaco during the 1931 spring season. These give Break O'Day 368 normal fruits to 84 puffed (19%), and Cooper's Special 324 normal to 145 puffed (31%). Numbers of puffed and normal fruit have been presented when not already published, as well as percentages of puff, to give some idea of the validity of the latter. While such field data are unsatisfactory for a close comparison between two varieties, they do give an indication of the relative amount of puffing. Calculation of varietal results to a standard set of environmental conditions would be an ideal method of comparison, but this is as yet impossible.

During the six-year period under consideration (1931 to 1936) the range in percentage of puffing for Bonny Best at College Station has been from 5.5 (determined from only 36 fruits) to 52. This includes a total

Table 41. Comparison of varieties—Weslaco, spring 1928. Based on weight of total fruit for each picking.

Variety	Strain No.	Row No.	June 12		June 22		July 2		Per cent puffed		
			Lbs. fruit		Lbs. fruit		Lbs. fruit		12	22	2
			Normal	Puffed	Normal	Puffed	Normal	Puffed			
Beauty	..	24	2.25	0.75	22.00	1.25	18.75	6.50	.....	5.4	26
Beauty	..	54	8.50	3.00	50.50	13.00	15.25	2.75	26	21	15
Burbank	19	23	11.75	3.50	56.25	1.00	46.75	5.00	23	1.7	9.7
Burbank	19	53	28.25	1.50	168.50	8.00	43.50	2.75	5.0	4.5	6.0
Clark's Early	25	30	11.25	4.00	69.50	3.25	10.25	3.50	26	4.4	26
Clark's Early	25	56	13.00	2.50	25.00	6.00	13.50	2.75	16	19	17
Cooper's Special	7	8	12.75	2.75	56.00	15.00	4.00	3.50	18	21	.....
Cooper's Special	7	38	11.75	3.25	72.50	11.50	34.50	12.50	22	14	27
Cooper's Special	8	9	5.50	0.75	23.00	4.00	59.00	9.75	.....	15	14
Cooper's Special	8	39	26.00	4.50	72.75	16.75	14.75	4.50	15	19	31
Cooper's Special	..	27	2.00	1.00	20.00	12.00	10.75	6.50	.....	38	38
Duke of York	18	22	2.00	0.00	21.00	1.75	15.25	4.75	.....	7.7	24
Duke of York	18	52	2.25	0.75	30.00	4.25	16.00	3.00	.....	12	16
Globe	1	11	3.00	1.75	17.25	11.00	27.25	16.25	.....	60	37
Globe	1	16	3.75	3.00	51.75	34.00	23.50	19.75	.....	40	46
Globe	1	21	1.00	0.50	26.25	8.50	30.75	15.50	.....	25	34
Globe	1	26	1.25	0.75	61.00	33.50	12.50	6.75	.....	35	35
Globe	1	31	0.75	0.50	18.75	10.75	7.75	4.00	.....	36	34
Globe	1	36	8.00	4.00	37.75	17.75	12.00	6.25	33	32	34
Globe	1	41	3.25	1.75	36.00	18.50	22.25	8.50	.....	34	28
Globe	1	46	2.50	2.00	53.50	27.50	14.25	7.75	.....	34	35
Globe	1	51	3.75	2.25	52.25	21.50	22.00	9.50	.....	29	30
Globe	12	14	1.00	1.00	25.50	12.50	22.00	8.75	.....	33	29
Globe	12	44	5.00	2.75	35.25	7.75	14.00	6.25	.....	18	31
Globe	21	25	0.75	1.75	29.00	14.50	14.50	5.25	.....	33	27
Globe	21	55	7.25	5.25	66.00	35.00	18.50	9.25	43	35	33
Gulf State Market	10	12	14.50	5.00	36.50	11.00	26.50	10.75	26	23	29
Gulf State Market	10	42	12.50	4.00	46.50	10.25	8.75	4.25	24	18	33
Gulf State Market	11	13	8.25	2.00	30.25	5.25	13.25	6.25	20	15	32
Gulf State Market	11	43	24.00	9.50	93.25	10.75	18.50	6.00	28	10	25
June Pink	15	18	30.00	5.00	44.25	1.25	42.25	11.00	14	2.7	21
June Pink	15	48	11.25	2.00	155.25	7.25	31.25	7.25	15	4.5	19
June Pink	16	19	8.50	2.00	37.00	3.00	69.25	18.75	19	7.5	21
June Pink	16	49	22.25	3.75	134.75	9.25	26.00	2.50	17	6.4	8.8

Table 41. Comparison of varieties—Weslaco, spring 1928. Based on weight of total fruit for each picking.—Continued

Variety	Strain No.	Row No.	June 12		June 22		July 2		Per cent puffed		
			Lbs. fruit		Lbs. fruit		Lbs. fruit		12	22	2
			Normal	Puffed	Normal	Puffed	Normal	Puffed			
Louisiana Pink	14	17	6.00	3.00	48.25	19.25	47.00	20.00	33	29	30
Louisiana Pink	14	47	11.75	6.00	79.50	33 50	38.00	15.75	34	30	29
Marglobe	2	2	3.50	2.00	6.75	5.00	6.25	3.75	.....	43	38
Marglobe	2	32	6.00	4.25	12.00	5.25	0.25	0.25	42	30	.....
Marglobe	3	3	3.25	0.50	21.00	4.00	8.25	3.25	.....	16	26
Marglobe	3	33	11.75	5.50	23.00	6.50	8.50	3.00	32	22	26
Marglobe	4	4	2.50	0.75	10.50	7.25	5.00	3.00	.....	41	38
Marglobe	4	34	3.00	2.75	29.50	15.00	4.50	1.75	48	34	28
Marglobe	5	5	3.25	0.50	8.00	6.50	2.50	1.50	.....	45	38
Marglobe	5	35	9.00	9.00	29.75	15.50	4.50	2.75	50	34	38
Marvelosa	6	7	7.00	1.00	31.00	3.50	26.00	2.75	.....	10	10
Marvelosa	6	37	27.00	7.00	59.25	6.25	15.00	4.75	21	10	24
Norton	17	20	2.50	2.00	9.75	2.75	9.75	3.75	.....	22	28
Norton	17	50	21.00	3.00	18.25	8.75	7.75	3.50	13	42	31
Rosy Morn	13	15	4.50	3.75	23.00	5.00	18.00	5.75	.....	18	24
Rosy Morn	13	45	1.50	2.25	41.25	8.00	12.50	3.75	.....	16	23
Self Topper	9	10	13.25	3.00	59.25	16.75	18.00	8.00	19	22	41
Self Topper	..	40	19.25	6.50	69.00	13.00	19.25	4.75	25	16	20

Table 42. Comparison of varieties—Weslaco, fall 1929. Based on No. 1 fruits for two pickings.

Variety	Row No.	October 30		November 16		Per cent puffed	
		No. fruit		No. fruit			
		Normal	Puffed	Normal	Puffed	Oct.	Nov.
Cooper's Special	2	1	40	7	54	98	89
Earliana	15	38	71	88	43	65	33
First Early	6	36	44	39	26	55	40
Globe	13	0	14	1	26	.....	96
Gulf State Market	11	5	51	14	63	91	82
John Baer	9	27	81	54	85	75	61
Marglobe	3	3	14	7	26	.....	79
Marglobe	7	3	29	7	42	91	86
Marglobe	8	4	41	10	57	91	85
Marglobe	10	3	22	3	29	88	91
Marglobe	12	2	43	3	31	93	91
Marglobe	14	0	22	5	22	.....	82
Norton	4	1	28	10	41	97	80

Table 43. Comparison of varieties—Weslaco, spring 1930. Based on approximately 100 fruits.

Variety	Row No.	Date taken	No. normal	No. puffed	Per cent puffed
Avon Early	12	May 30	70	30	30
Bonny Best	4	May 27	55	45	45
Clark's Early	24	June 2	56	44	44
Cooper's Special	2	May 27	11	89	89
Earliana	20	May 30	57	43	43
Fargo	22	June 2	51	49	49
First Early	18	May 30	56	44	44
Globe	16	May 30	42	69	62
Gulf State Market	14	" 30	47	63	57
John Baer	10	May 30	56	44	44
Louisiana Pink	8	May 27	54	46	46
Marglobe	1	May 27	23	77	77
Marglobe	3	" 27	10	90	90
Marglobe	9	" 30	15	85	85
Marglobe	11	" 30	11	89	89
Marglobe	13	" 30	5	95	95
Marglobe	15	" 30	2	98	98
Marglobe	17	" 30	4	96	96
Marglobe	19	" 30	9	91	91
Marglobe	21	" 30	19	102	84
Marglobe	23	June 2	7	93	93
Marglobe	25	" 2	10	90	90
Marglobe	27	" 2	21	79	79
Nicholson's 498	26	June 2	59	41	41
Norton	6	May 27	40	60	60

Table 44. Comparison of varieties—Weslaco, spring 1932. Based on total fruit harvested June 6.

Variety	No. normal	No. puffed	Per cent puffed	Notes
Bonny Best	15	15	50	Field grown
Bonny Best	66	34	34	Potted in cold frame
Bonny Best	42	28	40	Transplanted to field
Break O'Day	70	30	30	
Earliana	38	22	37	
Fargo	74	26	26	
Marglobe	6	23	79	
Pritchard	57	43	43	
Whole Salad	52	14	21	

Table 45. Comparison of varieties—Weslaco, spring 1934. Based on a 25-fruit sample at each of three pickings.

Variety	Row No.	No. normal	No. puffed	Per cent puffed
Bonny Best	1	63	12	16
Bonny Best	5	65	10	13
Bonny Best	9	59	16	21
Break O'Day	11	59	16	21
Chalk's Jewel	2	64	11	15
Cooper's Special	8	51	24	32
Dwarf Champion	312*	52	11	18
Dwarf Champion	311*	24	16	40
Ferry's 100	3	70	5	6.7
June Pink	6	73	2	2.7
Gulf State Market	7	54	21	28
Gulf State Market	313*	124	7	5.3
Gulf State Market	314*	32	4	11
Marglobe	10	39	36	48
Morse Special 498	4	67	8	11
Pritchard	12	49	26	33

*Selection number.

Table 46. Comparison of varieties—Weslaco, spring 1936. Per cent puff based on 100 fruits each harvest.

Variety	Row No.	May 20			May 28			June 10		
		Mod.	Severe	Total	Mod.	Severe	Total	Mod.	Severe	Total
Biltmore	22	20	21	41	28	14	42	34	20	54
Bonny Best	18	13	7	20	13	7	20	45	23	68
Break O'Day	6	59	13	72	46	10	56	62	21	83
Clark's Early	1	22	2	24	30	8	38	52	11	63
Glovel	4	36	5	41	72	9	81	70	10	80
Glovel	12	63	11	74	54	7	61	73	4	77
Grothen Globe	11	48	11	59	52	5	57	64	6	70
Gulf State Market	8	38	19	57	30	11	41	49	16	65
June Pink	10	34	14	48	22	11	33	.....	.....	.....
L. S. U. No. 10	16	47	4	51	40	14	54	69	16	85
Marglobe	9	68	15	83	77	5	82	91	1	93
Marglobe	14	59	10	69	61	8	69	73	19	92
Master Marglobe	19	54	14	68	59	6	65	58	24	82
Pritchard	7	53	8	61	44	4	48	61	8	69
Pritchard	13	52	11	63	42	6	48	84	2	86
Pritchard	17	47	10	57	47	8	55	51	28	79
Purple Pritchard	15	12	12	24	28	7	35	51	13	64
Rutgers	3	44	15	59	57	3	60	74	13	87
Scarlet Dawn	2	46	8	54	54	16	70	88	3	91
Stokesdale	20	26	12	38	26	8	34	34	27	61
Texas Special	5	10	10	20	5	2	7	24	8	32

of 24 lots, involving not over seven commercial strains, possibly fewer. Lots No. 7 and No. 39 and their progeny were grown four years. Averages of the per cent of puffed fruit for each of four seasons are presented in Table 47. The summer and fall crops of 1934, although from the same

Table 47. Average percentages of puff for two strains of Bonny Best for different harvest seasons—College Station.

Year	No. 7	No. 39
1932	26.7	22.2
1933	15.5	16.1
1934[1]	46.0	48.1
1934[2]	31.2	28.1
1935	23.4	26.8
Average	28.6	28.3

1 Summer
2 Fall

plants, are listed separately. The widest difference, a matter of 4.3 points, occurred during 1932. The average for the entire period is 28.6 per cent for No. 7 and 28.3 per cent for No. 39. In spite of wide variation in environmental conditions during this four-year period it seems safe to assume that the two strains are either very similar or identical for those hereditary factors affecting puffing and that the variation between seasons can definitely be assigned to environmental causes.

In contrast to these results we find that averages for Gulf State Market 32 and 73 for about the same period show considerable difference between the two (Table 48). With the exception of the 1933 season No. 73 had very much less puff than did No. 32. It thus appears that strains, as well

Table 48. Average percentages of puff for two strains of Gulf State Market for different harvest seasons—College Station.

Year	No. 32	No. 73
1932	43.2	18.4
1933	18.5	20.6
1934*	30.1	13.6
1935	16.8	7.1
Average	27.1	14.9

*Fall crop.

as varieties, that differ genetically can be distinguished over a period of years under field conditions. Such differences are apparent even though environmental conditions were only approximately the same for the strains and varieties being compared. Small differences might easily be masked by effects due to the environment where special precautions are not taken.

Attention is called to certain low puffing strains listed in Table 19: Bonny Best 710, Earliana 440, Kanora 597, Marketeer 631, Stone 661, and Success 663. A globe strain received from France under the name "Globularia wilkomi" has a large, attractive fruit and gives indication of

a very low amount of puff under conditions at College Station. Such strains have immediate use in supplanting those with a higher proportion of puffed fruit in commercial production and are also useful in breeding to give varieties having a minimum of loss on this account.

Selections: During the 1932 season at College Station seed was saved from individual plants exhibiting low and high amounts of puffing for 18 varieties and strains. Seventeen of these paired selections were grown in adjacent rows the following season for comparison. Results for the 1933 season have already been presented in some detail (25). In spite of the fact that selections were in some cases based on a small sample, the total fruit from the 17 selections for minimum puffing included 6684 normal and 1711 puffed fruits (20.4%) while the high puff selections produced 7525 normal and 2648 puffed fruits (26.0%). This difference was found to be significant. Since the plants were grown in adjacent rows in the field, the environmental influence must have been quite similar for each member of the pair as all plants were handled alike. Even supposing there were marked environmental differences between the paired selections, it hardly seems possible that most of the time these differences could have been favorable to less puff in the case of the low puff selections and to high puff for the high puff selections. The tendency of the uncontrolled environmental factors would be to mask rather than to emphasize small genetic differences.

The inclusion of the selections for extremes of puffing with the other lots, which were planted on land infested with the southern wilt organism for the purpose of selection for disease resistance, together with the extreme drought of the 1934 season, greatly reduced the number of paired selections by the elimination of one or even both members of a pair. While lot No. 116 of Dwarf Champion was lost in this way, No. 117, an additional selection, remained for comparison with No. 115. The interesting feature of the data is the contrast in behavior during the two harvest periods (Table 49). No. 117 behaves more like the parent, which in

Table 49. Comparison of selections of Dwarf Champion—College Station.

Year	No. 115 Per cent puff			No. 117 Per cent puff		
	First[2]	Second[2]	Average	First[2]	Second[2]	Average
1932[1]	40	23	31.6	40	23	31.6
1933	20	19	19.9	22	11	16.3
1934	.....	.....	.....	30	28	29.2
1935	18	22	20.2	49	6.6	27.7

1 No. 70, the parent from which the selections were made.
2 Harvest period.

1932 had a marked drop in amount of puff as the season advanced. The drop for No. 117 was not great in 1934 because of temperature complications; the second period in this case was in the fall, which was fairly moist. No. 115 showed no appreciable decrease during 1933 and an actual increase during 1935. While this difference can not be considered fully established, it is an indication that such relative differences in

amount of puff between strains or varieties found under one set of environmental conditions can not be expected to hold for another set of conditions, as may obtain earlier or later in the season, or in another year or geographical area.

Later results with selections No. 139 and No. 140 of Gulf State Market 73 are as yet inconclusive. During 1933 there was a marked difference between the two selections (Table 50). Practically no data were obtained during 1934. The following season the two selections were fairly close together. Additional data are necessary to establish a difference between the two selections over a period of years.

Table 50. Comparison of selections of Gulf State Market during different years—College Station.

Year	No. 139			No. 140		
	First	Second	Average	First	Second	Average
1932*	24	13	18.5	24	13	18.5
1933	6.8	17	11.9	17	41	29
1935	.....	.....	.....	13	.....	.....
1935	11	0	.....	11	3.4	7.2

*No. 73 from which the selections were made.

The two selections of Early Detroit did not show a difference in 1933. During 1935 one of these was compared with a similar selection from the original lot (No. 5). One had 22 per cent puff during the first period and 9.7 per cent during the second, with an average of 15.8. The corresponding figures for the other selection are 20, 7.9, and 13.9 for the average. Here again additional data are necessary for a satisfactory conclusion as to results to be expected for more than one season.

Table 51. Results of crossing Dwarf Champion and standard types—College Station. Based on total fruit each period.

Lot No.	Year	Generation	Location	First harvest period			Second harvest period			Per cent puffed	
				Data taken	No. fruit		Data taken	No. fruit		First	Second
					Norm.	Puffed		Norm.	Puffed		
176	1933	F_1	14	June.....	492	51	July.....	324	35	9.4	14
289	1934	F_2	2G	July 25.....	2	0	Oct.-Nov...	50	7	....	12
414	1935	F_3	4A	June 11....	177	55	July 12.....	113	5	24	4.2
414	1935	F_3	5A	June 29....	236	18	July 12.....	17	4	7.1	....
414	1935	F_3	6A	June 29....	322	25	July 12.....	48	8	7.2	14
414	1935	F_3	7A	June 13....	144	53	July 12.....	193	9	27	4.5
415	1935	F_3	12B	June 22....	353	94	July 15.....	212	33	21	14
415	1935	F_3	7C	June 28....	283	33	July 16.....	82	3	10	3.5
415	1935	F_3	12C	June 28....	290	38	July 16.....	82	2	12	2.4
415	1935	F_3	3D	July 2.....	251	17	July 16.....	26	0	6.3	....
415	1935	F_3	7E	July 4.....	282	32	July 17.....	48	3	10	5.9
675	1936	F_4	....	.....	34	6	.....	43	24	15	36
681	1936	F_4	....	.....	77	6	.....	33	6	7.2	15
682	1936	F_4	....	.....	33	4	.....	20	6	11	....

Table 52. Comparison of amount of puff in dwarf and standard segregates. Third generation. College Station, 1935.

Location	First Period						Second Period					
	Dwarf			Standard			Dwarf			Standard		
	No. norm.	No. puffed	Per cent puffed	No. norm.	No. puffed	Per cent puffed	No. norm.	No. puffed	Per cent puffed	No. norm.	No. puffed	Per cent puffed
4A.....	18	12	40	159	41	21	41	2	4.7	72	3	4.0
5A.....	33	4	11	203	14	6.4	12	3	20	5	1	17
6A.....	32	6	16	290	19	6.1	10	0	....	38	8	17
7A.....	13	17	57	131	36	22	46	2	4.2	147	7	4.5
12B.....	31	22	42	322	72	18	51	1	1.9	161	32	17
7C.....	46	14	23	237	19	7.4	35	3	7.9	47	0	....
12C.....	80	11	12	210	27	11	21	0	....	62	2	3.1
3D.....	26	3	10	225	14	5.8	20	0	....	6	0	....
7E.....	11	5	31	271	27	9.1	12	2	14	36	1	2.7

Crosses: Two sorts of crosses have been made at College Station, one involving the Dwarf Champion with a standard type and a Gulf State Market-Stone cross. Results of the first are presented in Table 51. All plats have a relatively small amount of puff. Both third generation populations have distinctly less puff than Dwarf Champion for the comparable harvest period. The record of the pollen parent of this cross was lost but it was one of two varieties, Bonny Best 33 or Earliana 1 or 45. All three of these lots had a somewhat higher percentage of puff in 1932 than Dwarf Champion 70 (Table 13).

The second generation and both third generation populations segregated for the dwarf plant character, which is a simple recessive. The amount of puffing in dwarf and standard plants in the third generation plats is compared in Table 52. It will be noted that during the first harvest period the dwarf plants have more puff in every instance, very much more in most cases. The values of chi square for this period are 25.98 for the population listed first and 22.66 for the one given below. This shows that the difference is highly significant. During the second period there seems to be less difference between the two growth types, chi square being 0.328 for the first and 4.84 for the second family. The Dwarf Champion had somewhat less puff than the pollen parent. If there is a linkage between genes for dwarfness and puffiness the F_2 plant selected as parent for the F_3 must have been a cross-over.

Table 53. Results of crossing Gulf State Market 73 x Stone 76. Based on total fruit.

Lot No.	Year	Generation	First harvest period			Second harvest priod			Per cent puffed	
			Data taken	No. normal	No. puffed	Data taken	No. normal	No. puffed	First	Second
73	1932	P_1	June.....	671	214	July.....	371	53	24	13
76	1932	P_1	June.....	165	133	July.....	332	173	44	34
173	1933	F_1	June.....	314	34	July.....	94	45	9.8	32
282	1934	F_2	June-Aug...	13	12	Oct.-Nov...	96	26	....	21
416	1935	F_3	June 27....	80	14	July 16.....	1	4	15	....
419	1935	F_3	June 11....	26	9	July 12.....	48	11	26	19

Table 54. Results of crossing Stone 76 x Gulf State Market 73. Based on total fruit.

Lot No.	Year	Generation	First harvest period			Second harvest period			Per cent puffed	
			Data taken	No. normal	No. puffed	Data taken	No. normal	No. puffed	First	Second
174	1933	F_1	June.....	303	32	July.....	156	34	9.6	18
285	1934	F_2	June-July..	12	15	Oct.....	6	1	....	....
423	1935	F_3	July 6.....	26	5	July 15.....	20	2	16	....
424	1935	F_3	July 12.....	28	3	July 17.....	5	1	9.7	....
427	1935	F_3	July 5.....	20	13	July 17.....	9	3	39	....
429	1935	F_3	July 6.....	34	4	July 15.....	7	4	11	....
Total	1935	F_3	July.....	108	25	July.....	43	10	19	19
691	1936	F_4	.....	44	7	.....	30	18	14	38

Table 55. Results of crossing Stone 9 x Gulf State Market 73. Based on total fruit.

Lot No.	Year	Generation	First harvest period			Second harvest period			Per cent puffed	
			Data taken	No. normal	No. puffed	Data taken	No. normal	No. puffed	First	Second
9	1932	P_1	June.....	170	130	July.....	233	97	43	29
73	1932	P_1	June.....	671	214	July.....	371	53	24	13
175	1933	F_1	June.....	36	3	July.....	37	21	7.7	36
287	1934	F_2	June-Aug...	21	14	Nov.....	8	3	40	....
431	1935	F_3	July 1.....	227	31	July 15.....	85	24	12	22
432	1935	F_3	July 8.....	37	16	July 16.....	....	....	30	....
433	1935	F_3	July 6.....	108	12	July 17.....	57	2	10	3.4
688	1936	F_4	.....	46	7	.....	63	32	13	34
728	1936	F_4	.....	5	0	.....	24	10	....	29
741	1936	F_4	.....	31	2	.....	29	24	6.1	45

Results of three crosses involving Stone and Gulf State Market are presented in Tables 53, 54, and 55. During the first harvest period the three first generation families had about the same amount of puff as the best selection of Gulf State Market grown in 1933. During the second period two of the F_1 populations had more puff than this selection, but no more than other strains. A selection of the Stone parent was not grown this season. Three lots of Early Stone were grown. These had considerably more puff than the crosses.

During the 1935 season third generation selections varied from 10 to around 40 per cent, the latter figure being based on a small sample. The lower amount is about what was obtained from Gulf State Market during this period (No. 380 had only 5.0 per cent puff). The range during the second period was about the same for both. One lot of Early Stone had considerably more puff during the second harvest period.

No satisfactory comparison is available for the fourth generation selections. They appear to be better than most of the large-fruited sorts but no better than the best strains of these.

During the winter of 1935-36 double crosses were made in the greenhouse between third generation selections of the two types of crosses discussed above. The puffing data obtained in the field the following season are presented in Table 56. The amount of puffing in these is, in general,

Table 56. Results of double crosses involving four varieties—College Station, 1936. Based on total fruit.

Lot No.	Parentage	First harvest period		Second harvest period		Per cent puffed	
		No. normal	No. puffed	No. normal	No. puffed	First	Second
726	174 x 176	111	6	88	29	5.1	25
715	176 x 174	68	7	32	9	9.3	22
733	176 x 174	35	5	30	9	13	23
737	176 x 174	31	2	14	6	6.1	.....
Total	176 x 174	134	14	76	24	9.5	24
724	175 x 176	59	3	43	15	4.8	26
729	175 x 176	103	12	42	16	10	28
735	175 x 176	46	3	64	29	6.1	31
Total	175 x 176	208	18	149	60	7.9	28
712	176 x 175	41	2	19	10	4.6	.....
716	176 x 175	68	6	59	27	8.1	31
725	176 x 175	40	3	11	8	7.0	.....
727	176 x 175	30	1	11	2	3.2	.....
740	176 x 175	18	0	7	4	.....	.....
Total	176 x 175	197	12	107	51	5.7	38

less than that of the fourth generation selections of the two crosses grown this season. The range for the 12 families of double crosses for the first period is 3.2 to 13 per cent and for the second period 22 to 38 per cent puffed fruits. This increased amount of puffing during the second harvest period is ascribed to the large amount of rainfall after May 20. Only two "large-fruited" varieties (Beauty of Lorain and Kanora) were within this range.

In addition to the controlled crosses, several lots were grown from accidental crosses between large and small fruited types. The results secured during 1935 are presented in Table 57. A lot secured from Dr. T. M. Currence of the Minnesota Station has been included here because of the rather small size of the fruit and the similarity in behavior to

Table 57. Crosses with small-fruited types—College Station, 1935. Based on total fruit each harvest period.

Seed parent	Lot No.	Year grown	Data taken	No. fruit		Data taken	No. fruit		Per cent puff	
				Normal	Puffed		Normal	Puffed	First	Second
Minnesota.....	315	1934	June.....	114	0	July-Aug.	24	4	0.0	.....
Minnesota.....	406	1935	July 2...	57	4	July 16...	30	0	6.6	0.0
Dwarf Champion	349	1935	June 25..	440	36	July 15...	264	14	7.6	5.0
Globe.....	371	1935	July 5....	37	0	July 17...	18	0	0.0	.....
Marglobe.....	392	1935	June 28..	199	3	July 16...	140	1	1.5	0.7
Marglobe.....	397	1935	July 5....	90	9	July 17...	9	1	9.1	.....
Gulf State Mkt..	377	1935	July 7....	420	16	July 17...	112	3	3.7	2.6
Stone x Gulf State Market..	430	1935	July 3....	261	3	July 17...	183	0	1.1	0.0

crosses of large and small fruited sorts. The crosses are all second generation populations, since in each case the F_1 was discovered as a single plant with fairly small fruits and very little puff among a family with normal sized fruits and considerable puff. The uniformly small amount of puff obtained in these lots is quite striking. Even in the cases where

Marglobe, which puffs badly, is the seed parent, less than 10 per cent of the fruits are puffed. Dominance of small fruit size was to be expected. During the 1936 season selected third generation families and crosses with a large fruited variety were grown. Of these populations lots 696 and 700 involving Globe and Marglobe (Table 58) had the smallest fruit

Table 58. Crosses with small-fruited types—College Station, 1936. Based on total fruit each harvest period.

Seed parent cross	Lot No.	First harvest period		Second harvest period		Per cent puffed	
		No. fruit		No. fruit			
		Normal	Puffed	Normal	Puffed	First	Second
Dwarf Champion	695	156	0	121	13	0	9.7
Globe	696	446	1	242	1	0.2	0.4
Marglobe	700	201	2	164	2	0.98	1.2
Gulf State	723	53	1	43	5	1.8	10
Gulf State	731	87	1	53	19	1.1	26
Stone x Gulf State Market	704	65	6	39	0	8.4	0
(Gulf State Market x sm. fr.) x Bonny Best	717	74	3	27	12	3.9	31
(Gulf State Market x sm. fr.) x Kanora	739	34	0	45	5	0	10
Kanora x (Gulf State Market x sm. fr.)	738	46	3	44	16	6.1	27
739 + 738	.....	80	3	89	21	3.6	19

and lot 717, the "backcross" to Bonny Best, had the largest, indicating a slight increase in proportion of puffed fruit with an increase in fruit size.

Discussion: With a character as responsive to environmental conditions as tomato puff, slight hereditary differences will be entirely covered up where the lots compared are subjected to different growing conditions. Large genetic differences such as obtain between most of the small fruited varieties and Globe are evident for all ordinary field conditions, and perhaps might be under any conditions. Even among large fruited sorts, if environmental factors are neglected, there is little overlapping under field conditions between varieties such as Kanora and Marglobe.

Such hereditary differences are the basis of a search for low puffing strains of commercial varieties and a breeding program to secure new varieties with a minimum amount of puff. Strains that have under 10 per cent of their fruit puffed as classified in this report will have practically no loss on this account under commercial conditions. This is because there are few if any severely puffed fruits where the proportion of abnormal fruits is low. No strain of Marglobe has yet been found with a reasonably low amount of puff. Considerable difference has been found among strains of Gulf State Market, but a strain satisfactory from this standpoint has not yet been found. The best strains of Bonny Best, Earliana, Stone, and a number of others are very promising.

As with other characters, the crosses are based on securing a recombination of factors. Several factors are obviously involved, the plan being to replace genes favoring puffing with those favoring normal development in case different loci are involved in different varieties. The selections of the

two original crosses between large-fruited varieties can not be considered better than the best strain of the parents involved. The first generation of the double cross does represent a marked improvement. Both selfed populations and crosses to new low-puffing varieties will be grown to secure constant lines with little puff.

The crosses to the small-fruited varieties have given populations with less puff than those from the above crosses, but they have the disadvantage of relatively small fruit. "Backcrosses" to new low-puffing large-fruited varieties are being made. Progress along this line probably depends upon crossing over between genes for defective fruit and those for fruit size.

Results of the puffing investigations thus far indicate that the best practical solution of the problem lies in growing only strains that are known to have a minimum of puffed fruit under ordinary field conditions rather than to manipulate the environment to reduce the amount of puffing.

In considering the origin of differences among varieties as to amount of puff it should be pointed out that the garden tomato as now grown is vastly different from the wild types from which it originated. The Cherry tomato grows as an escape in Texas and is well adapted, in that it grows vigorously, sets fruit during the entire summer, and has no puff to speak of. The development of the modern large-fruited tomato from a similar wild parent took place in Europe and in the northern United States under climatic conditions different from those in the Southwest. It is not so surprising, then, that our present varieties lack the adaptability of their ancestors when grown under the conditions here, and that conditions that differ from the optimum obtaining where they were being evolved result in the defective development of a greatly modified fruit. The environmental conditions that favor puffing may thus be considered as deviations from the optimum for tomatoes as now genetically constituted. There was no opportunity during the development of the large-fruited sorts for selecting those factors or combination of factors that might have resulted in a tomato having both perfect adaptability to Texas conditions and an acceptably large fruit. It is possible that this ideal cannot be perfectly attained, but the wide variation observed among the different varieties and the evidence from the crosses suggest that this can be done.

SUMMARY

Tomato puff is a defect of the fruit, in which the seed-bearing tissue develops abnormally, leaving a partially hollow fruit or one in which the cross walls have grown to fill the seed cavity. It was noted at this station as early as 1895.

Defective fruits can be identified at a very early stage, although the abnormality is thought to develop later at times.

The proportion of fruits affected varies widely (from 0 to 100 per cent) with variety and growing conditions, depending upon hereditary and environmental factors.

Under greenhouse conditions, when high temperature was not a factor, plants with low available moisture had a smaller proportion of puffed fruits than plants with a large amount of available moisture. Such differences were greater for the first fruits harvested than for those harvested later.

The same relationship was found in only part of the irrigation experiments.

Plants sprayed with Bordeaux had less puff than those sprayed with a mixture of Bordeaux and a heavy oil spray. This is interpreted as a moisture relationship since Bordeaux increases, oil depresses, transpiration.

A general relationship was found between amount of rainfall and proportion of fruits puffed. If the amount of rainfall is higher earlier in the season, the proportion of puffed fruits is higher during the first harvest period than later. When more rainfall occurs later, there is a general increase in the proportion of puffed fruits.

Other factors, such as differences in varietal response to changes in available moisture, have been found to modify this expectation in certain instances.

When maximum temperatures in the greenhouse exceeded 100°F. the percentage of puffed fruits for all water treatments approached or reached 100. During the 1934 season in the field at College Station, the high maximum temperatures are considered to be responsible for the higher proportion of puff than was obtained later in the season with much more available water but cooler weather.

When maximum temperatures in the greenhouse remained below 100°F. there appeared to be a direct relationship between minimum temperatures and amount of puff. These did not get below 60°F.

These influences of water and temperature were found to be effective chiefly during the early development of the fruit. For this reason the date of fruit setting must be known if the influence of environmental conditions is to be studied. It also follows that for a comparison between any two lots, only fruit setting at approximately the same time can be used satisfactorily.

A comparison of plants grown in soils from northern and southern sources gives no indication that the freedom from puffing in the North is due to the presence of some minor element in soils of glacial origin which is lacking in soils in the South.

Less puff was found in every case at College Station where a 6-12-6 fertilizer was added. Results on the more productive soils on the Lower Valley station were inconsistent. It is pointed out that a reduction in proportion of puffed fruit accompanying a fertilizer application might be through its influence on the amount of free water in the plant.

Certain fertilizer supplements such as the sulphates of magnesium and iron were not found to affect the proportion of puffed fruits materially at the Lower Valley station.

No association was found between southern blight or blossom end rot and the proportion of puffed fruits.

Hand pollinating flowers of Marglobe in the field reduced the amount of puffing. A relation between available pollen and amount of puff probably explains the excessive amount of puffing when maximum temperatures exceed 100°F. While pollination is undoubtedly a factor in determining the amount of puffing under field conditions, it is not considered to be the dominant factor.

A satisfactory comparison of fruits from different clusters of the same plant is difficult because they must necessarily set at different times and a change in environmental conditions may be expected.

In spite of the important influence of environmental factors on puffing, varietal (hereditary) differences are found. The degree of difference that can be distinguished satisfactorily depends upon the amount of data and on the similarity of the environmental conditions affecting any two lots while the fruit is setting.

The small-fruited varieties, with the exception of Pomodora, all have little or no puff. Ranked according to increasing tendency toward puffiness, they are Currant, Cherry, Plum, and Pear.

Of the large-fruited sorts, those having oblate fruit with many locules puff less than those with globular fruit and few locules. Those with very large fruit having a tendency toward fasciation also have a high proportion of puff. Varieties of the Bonny Best type thus have been found to puff less than Globe and Marglobe. Low-puffing varieties include Kanora, Marketeer, and Success.

Differences have also been found between strains of the same variety. Low-puffing strains include Bonny Best 710, Earliana 440, and Stone 661.

Significantly more puff was observed among progeny of 17 individual plants selected for large amount of puff than from 17 plants from the same lots that were selected for low amount of puff.

Several hereditary factors for abnormal fruit are evidently involved and appear to be, for the most part, recessive. Crosses between large and small-fruited sorts are much nearer the latter in fruit size and puffing. Selections from crosses between commercial varieties have about the same proportion of puff as the best parent.

Crosses of two distinct third generation selections, involving four varieties, have a low amount of puff. This is expected to show segregation.

In crosses between dwarf and standard types the dwarf segregates in the third generation had more puff than the normal in spite of the fact that the dwarf parent appeared to have less puff than the standard.

The use of varieties and strains, selected for their ability to produce normal fruit under southern conditions, and the development of new low-puffing varieties by breeding would seem to be the only practical solution of the problem.

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