SOME FACTORS CONTRIBUTING TO TOMATO PUFFING

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Tomato puffing is a common fruit defect causing serious annual losses in Texas. The trouble is known by several names, such as "tomato puffs," "tomato pops," "puffy tomatoes," "puffs," and "pockets." The term tomato puffing, as is now generally used by tomato growers wherever the defect occurs, is preferred.

In 1895 Price and Ness (6) of the Texas Agricultural Experiment Station gave the first clear description of tomato puffing of the variety "Terra cotta" in which they seem to have accepted puffing as a varietal characteristic. In 1926 Lesley and Rosa (5) recognized puffing as a defect of some tomato crosses grown at Riverside, California. Weber and Ramsey (15) found the same trouble causing serious damage in Florida-grown tomatoes. Taubenhaus (7) in 1929, reported some preliminary observations on puffed tomatoes. Since then, Traub et al. (13, 14) and Yarnell et al. (17 to 25) and Corns (1) have added much to our knowledge of this trouble.

The most typical symptom of a puffed tomato is its angular appearance, with slightly indented walls which yield readily to the least pressure. In some varieties the flatness of the sides is not so conspicuous, but the light weight and the hollow "feel" of the fruit is a sure indication of puffing. A severely puffed fruit upon being sliced shows a partial to complete abortion of the placental tissues, which accounts for the hollow interior. Sometimes the locular walls are much proliferated and hardened. Tomatoes in which the hollow cavity is negligible are classified as no. 1 fruits and marketable, while fruits with prominent cavities are classed as culls.

To determine the prevalence of tomato puffing in the United States in 1933, a questionnaire was sent to plant pathologists and horticulturists in every state as well as in Alaska, Hawaii, Puerto Rico, and the Virgin Islands. The replies received reported tomato puffing of field-grown tomatoes in Alabama, Arkansas, California, Louisiana, Mississippi, and Texas, but only of greenhouse-grown tomatoes in Illinois and Michigan. During 1924, field losses were estimated at 14 per cent.; in 1925, 15 per cent.; in 1926, 20 per cent.; in 1927, 2 per cent.; in 1928 and 1929, 8 per cent.; in

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2 Deceased. This paper is one of the last written by the late Dr. J. J. Taubenhaus. It represents several years of experimentation and observation. One will note the habit of making large numbers of samples and cultures, so typical of his work. Not a hundred cultures, but two thousand; not a hundred fruits, but many bushels of them were examined. Since the original manuscript left his hands, only the changes suggested by readers of the manuscript have been made by the junior author.

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1930, 14 per cent. of the commercial Texas crop. Tomato growers and packers in Texas generally agree that losses from tomato puffing may vary not only from year to year, but even in the same season, depending on weather conditions. After a heavy or prolonged rainy spell greater culling is necessitated in both field and packing sheds, due to unusual increases in puffed tomatoes, while during dry weather, tomato puffing, although present, is generally unimportant.

It is generally believed by growers that puffing becomes noticeable only when the tomato fruits are fully developed and just before they begin to color. In order to determine whether puffing is a defect of the maturing fruit only, a systematic survey (8) was carried out during 1930 at 18 different locations in Texas. Tomato fruits in all stages of development were cut and the degree of puffing recorded. It was found that tomato puffing in its earliest and severest occurrence was just as prevalent in young embryonic fruit, even only 1.0 to 2.5 mm. in diameter, as in fully developed and maturing tomatoes.

As to susceptibility, Yarnell (17, 18, 22) found considerable variation among different tomato varieties; the Marglobe was the most susceptible, while the John Baer was the most resistant. The writers found that the John Baer variety was very susceptible to tomato puffing when grown under irrigation in the Winter Garden section of Texas. Soil moisture conditions seem to affect the susceptibility of a variety because during 1930 the Marglobe, a highly susceptible variety, showed 19 per cent. affected fruit when grown near Troup, 22 per cent. at Weslaco, and 46 per cent. when grown near Bryan, Texas.

Opinion as to the cause of puffing differs greatly. Some growers claim that the trouble is favored by the use of excessive amounts of fertilizer, particularly nitrate of soda, while others believe moisture to be the cause, since the greatest losses occur in seasons of continuous precipitation or after a heavy rain following a prolonged dry spell. Corns (1) found that in greenhouse studies puffing was associated with poor pollination, but that pollination was not a factor under field conditions. Foster and Tatman (2) after 5 years of study on puffing of tomatoes in the greenhouse, concluded that growth-limiting factors such as soil moisture, soil nutrients, and air temperature or combinations of these, may interfere with the normal development of the fruits.

During 1928 and 1929, about 2000 plate cultures on potato-dextrose agar were made from tissue of lightly to severely puffed tomato fruit, and in not a single instance was an infectious organism recovered. With no indication of a causal organism, one might first suspect that tomato puffing is either of a physiological nature or is induced by some virus. In order to determine whether tomato puffing is of a virus nature (8) Marglobe tomato
seeds were obtained during 1929 from apparently normal fruits. The next spring (1930) they were disinfected for 5 minutes in 1:2000 mercuric chloride, and planted in insect-proof cages at College Station. This test was repeated in 1931. During both years the plants in all the cages were hand pollinated to insure a crop of tomato fruits. About the middle of the growing season the plants in some of the cages were inoculated with freshly extracted, filtered juice obtained from freshly gathered, severely puffed tomatoes. This juice was passed through a Berkfeld filter, and used as inoculum, being either rubbed into the leaves and stems with a sterile brush, or injected with a hypodermic syringe. Check plants were rubbed or injected with distilled sterilized water. A small number of the inoculated and uninoculated plants in the cages showed mosaic. Puffed fruits occurred in all of the cages and on all the tomato plants, whether inoculated or not and whether naturally infected by mosaic or not. This suggests that tomato puffing is not caused by a virus, as otherwise the uninoculated and the non-mosaic-infected plants in the check cages should have produced normal tomatoes, which was not the case.

In 1932 (10) seed of Marglobe tomatoes were obtained from Wethersfield, Connecticut, where puffing is not known to occur. These seeds were surface sterilized for 5 min. in a 1:2000 mercuric chloride solution, planted in insect-proof cages at College Station, and thinned to a stand of nine plants per cage. The blossoms of all the caged plants were hand pollinated. A high percentage of puffed fruit occurred on all of the plants, whether these plants were naturally infected by mosaic or not. These results further suggest that puffing is not caused by any seed-borne virus, but they point to the probability of some environmental factors as the cause.

Seed from the same lot was surface sterilized and planted in steam-sterilized and unsterilized Lufkin fine sandy loam. All plants were dusted with insecticides frequently to keep them free of insects. Puffed fruit developed on all plants, regardless of soil treatment, indicating that puffing is probably not of an insect-borne virus nature.

If tomato puffing is not caused by a pathogenic organism or by a virus, then is it a trouble brought about by certain factors of environment acting on particular hereditary complexes? Several factors have thus far been tested including soil acidity, fertilizers, soil moisture, geographical location, and the effects of other diseases upon puffing.

During 1933 (12), Marglobe tomato plants were grown at College Station, in wooden containers which were filled with different known soil type materials and of known degrees of acidity. Container 1 was filled with Susquehanna fine sandy loam having a pH of 5.5; container 2 was filled with Tabor fine sandy loam with a pH of 6.7; container 3 was filled with Kirvin fine sandy loam with a pH of 7.1; and container 4 was filled with
Houston black clay soil with a pH of 7.7. No significant difference in the percentage of puffed fruits occurred in the different soil types used. In other experiments, earthenware cylinders filled with Lufkin fine sandy loam were adjusted to acidities varying from pH 4.9 to pH 8.5. A total of 4 cylinders were used for each pH adjustment and a single tomato plant was planted in each cylinder. There appeared to be no correlation between the soil acidity and the amount of puffed fruit in each cylinder.

Friend (3, 4) found that differential fertilizer treatments had no significant influence on puffing. Yarnell et al. (17 to 25), on the other hand, stated: "Differential fertilizer treatments did not affect the amount of puffing in the Lower Rio Grande Valley, although a difference was found at College Station," which might be explained by differences in soil fertility. The same authors also found that several varieties of tomatoes always produced less puff when fertilized with a 6-12-6 fertilizer.

In 1933, super-phosphate, sulphate of potash, and nitrate of soda in definite amounts and in various combinations were added to Lufkin fine sandy loam soil in galvanized cylinders which were set in the ground at College Station, Texas. A single Marglobe tomato plant was planted in each cylinder and regularly watered twice a week from June 1 to November 1, except during rainy weather. Puffed fruits were found on all plants irrespective of the fertilizer added to the soil.

The possible relationship of soil moisture to tomato puffing has been long suspected, as previously indicated by Texas and Florida tomato growers. Although the literature on this relationship is somewhat conflicting, the trend of experiments by various workers indicates a correlation of the amount of puffed fruit with the amount of moisture present in the soil. Friend (3, 4) found that the yield was greater and the percentage of puffy fruit lessened from plants receiving greater amounts of water at frequent intervals, whereas Yarnell (17 to 25) found: "In general the amount of puffing is greater where there is more available moisture." Wood (16) found that tomatoes grown without irrigation showed considerably less puffing than those grown with irrigation. This was especially true with the varieties Pritchard and Marglobe. During 1930, observations were made at Arp, Tyler, and Prairie View of tomatoes grown on dry upland soil, moist lowland soil, and under conditions of overhead irrigation. Lower percentages of severely puffed fruit occurred on plants growing on upland dry tight soil, while high percentages of puffed fruit were found on plants growing in seepy lowlands or on plants grown directly under irrigation. In 1932 and 1933 (10), Marglobe tomatoes were grown at College Station in plats receiving weekly irrigations and in plats without irrigation. The greatest percentage of normal tomatoes was produced on individual plants growing without irrigation. These experiments further indicate the relationship of soil moisture to tomato puffing.
It has been previously mentioned that there are certain sections in the United States where tomato puffing is unknown. Tomato seeds were obtained in 1932 from these sections. For comparison, tomato seed was also obtained from plants grown in Florida and Texas where annual losses from tomato puffing are heavy. The plants from each of these sources of seed were divided into two lots, eight of which were grown under irrigation and eight without irrigation. Irrespective of origin of the seed, puffing occurred in all strains and varieties, particularly when grown under irrigation. These studies suggest that puffing may be caused by various temperature, soil, or moisture conditions or other factors peculiar to some of the southern states. Tomato seed from sections where tomato puffing never occurs did not produce plants entirely free from affected fruit.

It was thought that the presence of other diseases on the tomato plant might be a factor in affecting the amount of puffed fruit. TRAUB (13) observed that mosaic-infected tomato plants produced more puffed fruits than normal plants. In our inoculation experiments tomato puffing appeared equally prevalent irrespective of natural mosaic infection. Tomato fields were examined in 1930, 1931, and 1932 to determine whether there was any correlation between the number of puffed tomato fruits per plant, and the infection of that plant by certain other organisms. Records were made of mature plants affected by mosaic (virus), Fusarium wilt (F. lycopersici), Septoria leaf spot (S. lycopersici), Alternaria leaf spot (A. solani), Cladosporium leaf mold (C. fulvum), and bacterial canker (Aplanobacter michiganense). Puffing occurred equally as often on plants infected with these diseases as on those which were non-infected. YARNELL et al. (25) found no relationship between the amount of puffing and injury to the plants by Sclerotium rolfsii. The same writers also observed that there was no association between blossom-end rot, a physiological disease caused by abnormal water relations, and the amount of puffing.

Summary

Tomato puffing is a fruit defect causing annual losses of 8 to 15 per cent. of the tomato crop in Texas. Affected fruits are light in weight, angular, and flat-sided, and more or less hollow. Puffing begins in the embryonic stage and progresses with the development of the fruit; the symptoms, however, are more prominent in fully developed tomatoes.

The cause of puffing is still unknown. The studies here reported seem to show that it is not caused by a microorganism nor a virus. Tomato puffing does not appear to be seed- or soil-borne, nor is it influenced by other diseases attacking the same plant, nor by soil acidity. The defect is influenced by soil moisture and probably by certain fertilizers, as well as some environmental
conditions. Irrigated plants produced a higher percentage of puffed fruits than did plants grown without irrigation.

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