(3.3%) was found in the low yielding No. 5 Homestead field. Both fields contained relatively high calcium levels (31.5 and 37.4% respectively).

The Wisconsin soil (No. 6), a heavy clay soil which was non-irrigated, is interesting as a comparison because the sole source of nutrients was manure.

The hydroponic solution (No. 7) is also interesting as a comparison in that concentrations and balances can be directly compared to soil solutions, and the effect of controlled variations on plant growth can be studied.

The analysis of leaf tissue (table 7) from the above mentioned fields indicated satisfactory percentages of most nutrients tested. It should be pointed out that time of sampling with respect to stage of growth and season can affect the interpretation of results obtained from the analysis of leaf tissue (5).

Summary

When the plant and fruit average composition are used as an indicator, approximately 320 lbs. of N, 60 lbs. of P and 440 lbs. of K (as an example of 3 major nutrients) are required for production of 1000 bu. of tomatoes per acre. Balance of the required nutrients in the soil solution is essential for production of highest yields and best quality. A total soluble salt concentration in the soil solution (indicator of nutrient level) of 2000 to 3000 ppm in the effective root zone is recommended. As balance factors, calcium should be maintained at about 15% of the total salt; potassium at 10%; and nitrate nitrogen at 3 to 10%. Deviation due to leaching or plant utilization can be alleviated by additions of certain nutrients at the proper time. Accumulations of salts or specific ions can also be controlled. A relatively high water table is essential for best results either with or without plastic mulch. At present the production goal for vine-ripe tomatoes should approach 2000 bu./A. and 1000 bu./A. for mature-green tomatoes.

LITERATURE CITED

1. Duncan, W. G. and A. J. Ohlrogge. 1959. Principals of nutrient uptake from fertilizer bands. II Root development in the band. Agron. Jour. 50:605-608.
2. Geraldson, C. M. 1957. Soil soluble salts—Determination of and association with plant growth. Proc. Fla. State Hort. Soc. 70:121-126.
3. Geraldson, C. M. 1962. Growing tomatoes and cucumbers with high analysis fertilizer and plastic mulch. Proc. Fla. State Hort. Soc. 75:253-260.
4. Goodall, D. W. and F. G. Gregory. 1947. Chemical composition of plants as an index of their nutritional status. Tech. Comm. No. 17. Imperial Bureau of Hort. and Plantation Crops, Aberystwyth, Wales.
5. Howard, D. F. et al. 1962. Nutrient composition. Calif. Agri. Expt. Sta. Bull. 788.
6. Orth, P. G. and R. W. Harkness. 1962. Intra seasonal variations in nutrient content of young tomato leaves. Proc. Fla. State Hort. Soc. 75:260-268.
7. Sims, G. T. and G. M. Volk. 1947. Composition of Florida-grown vegetables. Fla. Agr. Expt. Sta. Bull. 438
8. Wittwer, S. H. 1960. Practices for increasing the yields of greenhouse tomatoes. Mich. State Agri. Expt. Sta. Circ. Bull. 228.

SOME EFFECTS OF POOR POLLINATION IN TOMATO

James M. Walter

Gulf Coast Experiment Station

Bradenton

Introduction

The favorable-market period for spring-crop tomatoes grown in the Bradenton-Ruskin area ended on May 9 in 1959, 1961, and again 1963. Coupled with the failure of their crops to set fruit during March, this has meant that several growers have missed or nearly missed their market. This problem of large acreages of tomatoes going week after week making numerous flowers but setting few if any fruits has plagued the growers of the area for a decade, with many acreages planted in December delaying fruit-set until early May.

Complete failure to set fruit by a given date is only part of the problem. One-sided and dwarfed fruits that are not acceptable to the shipping market are other aspects of it that are often deceiving and costly to growers. "Puff" and "pockets" are expressions used by many to cover the one-sided or poorly filled, cull fruits commonly found to have no seed in one or more locules. Slow development and dwarfing of fruits are the effects of poor pollination that results in very few seed per locule. Seldom does a grower in the Bradenton-Ruskin area find it profitable to harvest tomatoes less than 5 oz. in weight, approximately the "6 x 6" size. It is not at all unusual in the area to find, when harvest has been completed on a staked acreage of the variety Homestead, that the average plant still has 20 dwarfed fruit, none weighing more than 3 oz., or being more than 2" in diameter, or having more than 10 seed.

The writer has been recording observations and striving for a better understanding of this costly problem for the past 6 years. The observations and data recorded to date do not yet form a clear and dependable picture, but they do appear to be narrowing the field in which the solution to the problem must be sought.

Breadth of Problem

Difficulty in obtaining timely and complete fruit-set in tomato culture is not limited to the Bradenton-Ruskin area. It is of general concern. In fact, it was the subject of the Campbell Soup Company's Plant Science Symposium of 1962, which included many leading students of the problem. Of course, a few other crops were mentioned briefly in this seminar, but nearly all of the papers concerned tomato, from either the practical or theoretical standpoint. The publication of the proceedings of this symposium brought the subject up-to-date and was a great service to tomato specialists. However, one can not read through this collection of papers without realizing how little is actually known about the factors controlling fruit-set in tomato. The writer does not find in it the answer to the problem in the Bradenton-Ruskin area. The varieties of tomato now important in Florida were not used in any of the experiments reported, of course. After studying all of the papers, the writer still had to think that our southern schools of botany have been avoiding the subject of pollination and fruit-set for the past 35 years. He has found nothing that amounts to scientific study of pollination (The term here used in the botanical sense.) in tomato in this country since H. W. Schneck (2) published his bulletin in 1928 on work done at Cornell in 1920 and 1921. Under impetus from the developing greenhouse culture of tomatoes in South Carolina, Dr. W. L. Ogle began studies at Clemson in 1962 of pollination-fruit-set in relation to nutrition, both major and minor elements being considered. To date, no publication resulting from this study has come to the writer's attention.

The Few Facts in Hand

On the environmental conditions affecting set of fruit by tomato a few statements generally acceptable as truth applicable in Florida may be made. These are, briefly:

1. Relative humidity down to 40% for long enough to make pollen dusty and then wind at approximately 20 m.p.h. for a few minutes are favorable for pollination. These are assumptions formulated after years of experience as far as the writer can determine, no experimental evidence having been found.
2. The pollen of Florida-bred tomatoes is not viable (and there is no fruit-set from either natural or artificial pollination) unless night temperature drops to approximately 72° F. Most greenhouse growers in the north prefer, of course, that the low be about 65° on plants that have already started setting some fruits.
3. Hot-weather-setting stocks developed in other states and reported to have viable pollen at 78° night temperature have not proven superior in setting fruits to Florida-bred stocks under summer conditions here.
4. Searing winds that damage stigmas and styles of tomato flowers in other parts of this country have not been considered a factor under Florida conditions, though it is recognized that a sandstorm does occasionally ruin flowers that are full-blown when it strikes. It is often observed here that female structures of the flowers remain in fresh green condition and set fruit from extraneous pollen as long as 10 days after loss of their own anther columns.
5. Low temperature, in the ranges that occur in Florida in winter, does not damage tomato pollen.
6. Studies by Curme (1) of fruit-set at low temperatures in the Phytotron at Passadena show that some types of tomato set well at 45° while others do better at 50° or higher. His results show clearly that light intensity is an important interrelated factor, especially on the variety Rutgers.

Observations

The spring-crop of 1958 was trying to the nerves of many of the Bradenton-Ruskin area because their acreages of Homestead delayed until early May to set enough fruits to make yields greater than 40 bu. per A. The season was unusually humid and calm through March and April, and it was considered that consistently high humidity was the reason for the difficulty. On our field at Bradenton where the numerous breeding stocks were growing, humidity and flower conditions appeared favorable for pollination on April 8, and it turned-out that the normal-vined stocks did set well on that date, but that Homestead and all of the related determinate lines failed to set. April 19 was the next date judged to be dry and breezy enough to favor pollination, but the determinates still did not set until another 10 days had elapsed. This made the crop entirely too late for proper evaluation.

The following year, one of the recent 3 in which the favorable-price shipping market ended on May 9, it was the commercial acreage on the most humid site (river-front) used in Manatee County that made the best early set, raising some doubt that excessive humidity alone is the major factor in the problem. The same acreage was again in tomato in 1960 and was managed from the standpoint of cultural practices just as it had been in 1959. However, the 1960 crop was beset by poor pollination to a degree that caused visiting tomato specialists from California to suggest that fruit-setting hormones should be applied. The marketable yield of the 1960 crop on this field was only one-third of what it could have been had the poorly-pollinated dwarfs developed to marketable size.

It was a striking feature of the 1960 spring-crop season in the Bradenton-Ruskin area that poor pollination afflicted some localities while others not more than 5 miles away were unaffected. Many observations were made, many questions were asked the growers, but nothing that could solve the puzzle was disclosed. One of the most interesting, seemingly pregnant, puzzles occurred in the acreage of a Ruskin grower using small (20 A.) fields enclosed by tall Australian pine wind-breaks. In one of these small fields the plants on the eastern fourth set fruits in good numbers at the proper time, while plants of the same stock on the remainder of the tract and on tracts immediately east, south, and west failed to set. The wind-break to the north was as uniform as could possibly be imagined and within the tract the exposures to sun and wind appeared equal. It seemed that here was a case in which it might be found that some difference in the application of sprays or fertilizers could account for the line between good set and poor set. The question was discussed at length with the grower, who had noticed the difference several days earlier. He could not think of anything in handling of the crop, spraying, feeding, cultivating, etc., that would match the line across the field.

For many years the writer has been observing numerous lines and varieties of tomatoes at Immokalee, Homestead, and Ft. Pierce that are also under trial at Bradenton, the seed of a given stock for the trials at the 4 locations having come from the same packet. As a result of this, it is possible to state with assurance that the poor pollination problem, though it occurs occasionally in the other 3 areas, is much more important at Bradenton. The difference is so great that it should be easy to explain, but is not.

In the 1963 spring-crop trial at Ft. Pierce, many stocks did show the same signs of poor pollination that one has come to expect at Bradenton. Since this was unusual, it appeared desirable to study the weather records of the Indian River Field Laboratory to see if they showed for 1963, any marked deviation from normal for that location. The signs of poor pollination apparent in the plots on May 8 were known to apply to flowers reaching anthesis during the latter half of March, this being a matter of judgment, acquired through the years, on the rate of development of fruits during the month of April. Table 1 presents the Indian River Field Laboratory data for the last 15 days of March, 1952-1963, on low temperature, rainfall, and relative humidity. Also shown are the figures on approximate numbers of hours per day that relative humidity sank below 40%.

These data in Table 1 show, for the period of March 21-24 inc., a weather condition that may account for the unusually poor pollination of crown hands observed in the plots. This is the occurrence of low temperature and low relative humidity at the same time. The writer has been aware all along that too many drives of cold, dry air strike Florida, but he had never suspected that one which failed to bring some rain could be interfering with pollination of tomato flowers. These weather data fitted to the field observation force consideration of the idea that humidity does possibly run too low at times in Florida for proper functioning of pollen and stigmas of tomato flowers. It may turn-out that this is the main factor in the problem of poor pollination in sand-land areas of Florida during winter and early spring; but, of course, records from several more locations for several seasons will be needed to corroborate this lead.

New Data on Extent and Duration of Chilling Effect

Observations accumulated for several seasons appeared to mean that crops of Homestead standing in the field during winter and early spring are sometimes radically upset by nights so cold that frost is threatened. With this variety among those under consideration, Dr. P. A. Young of the Tomato Laboratory, Jacksonville, Texas,

Table 1. Temperature, rainfall, and relative humidities at Indian River Field Laboratory, for last 15 days of March*

March	Low Temp. 1963	Low Temp. 12-yr. Av.	Rainfall 1963	Rainfall 12-yr. Av.	Rel. Hum., Low for Day 1963	Rel. Hum., Low for Day 11-yr. Av.	Approx.No.Hrs. below 40% R.H. 1963	Approx.No.Hrs. below 40% R.H. 11-yr. Av.
17	67	55.4	0	0.12"	31	37.4	3.5	2.7
18	62	55.3	0	0.28	30	39.6	7.0	2.9
19	62	56.9	0	0.19	28	37.8	3.5	3.3
20	68	57.2	0	0.30	33	36.5	5.0	3.4
21	53	56.4	0	0.01	14	35.3	14.0	5.2
22	44	56.3	0	0.43	33	32.2	5.0	4.8
23	40	51.9	0	0.10	25	39.6	10.0	2.7
24	48	57.7	0	0.15	27	40.7	10.0	3.4
25	53	57.6	0	0.18	45	42.8	0	2.5
26	56	55.9	0.02"	0.31	27	39.3	6.0	4.0
27	61	55.0	0	0.16	27	38.5	7.0	3.5
28	59	55.6	0.44"	0.04	41	43.3	0	2.0
39	63	58.3	0.21"	0.09	36	42.3	2.0	2.5
30	59	59.8	0.35"	0.11	59	45.5	0	0.7
31	67	59.9	0.32"	0.06	59	41.1	0	0.8
Av.	57.5	56.6	0.09"	0.21"	34.3	39.5	4.9	3.0
Dev. from Av.	+0.9		-0.12"		-5.2		+1.9	

*The writer is greatly indebted to N. C. Hayslip and Wilma Calhoun of the Indian River Field Laboratory for furnishing the records from which these data came.

stated (3) in 1957, "Generally, green-wrap tomatoes cannot set many fruits when night temperatures are cooler than 59° F." No definite statement could be found anent the variety on the low temperature required for obvious damage or on duration of chilling effect before the plants would start setting fruits again. In mid-March 1962 it appeared that circumstances in prospect for the next two weeks might allow collection of data on these questions. Thus, the tagging of normal, well-formed flowers under date that they first reached the stage of releasing dusty pollen was undertaken. This was done under the conditions of our Braden River field, and, as would be expected, unaccountable losses of tagged flowers have run high. Table 2 presents some data covering the last third of March, 1962. The plants were lightly frosted on March 7, and nights continued cold, nearly all below 50° F., through March 18; but March 19 was warm (low at 67° F.). Very few flowers on these Homestead 24 plants had reached anthesis before March 20.

It was soon apparent that the drop of temperature to 45° F. on the morning of March 20 had not greatly handicapped set of fruits for many hours, the counts made on March 30 disclosing that 72 percent of the flowers tagged on March 21 had set. The data afforded by the flowers tagged from the latter date through March 30, of course, served to corroborate this result, since the thermometer dropped to 52° F. on March 24 and to 39° on March 28.

However, it does no good to have a fruit set unless it will develop to marketable size. Thus, the most valuable data presented in Table 2 are those showing the percent of tagged flowers resulting in dwarfed fruits. It seems noteworthy

Table 2. Results in fruit-development from flowers tagged on 20 plants of Homestead 24 during latter third of March 1962 at Braden River field, Gulf Coast Experiment Station

Date of Anthesis	3/20	3/21	3/22	3/23	3/24	3/26	3/27	3/28	3/29	3/30
% Tagged flowers resulting in fruits*	27	72	53	44	50	70	88	49	50	44
% Tagged flowers resulting in dwarfed fruits**	69	48	53	50	28	23	12	35	50	11
Low temperature of date	45	58	65	54	52	60	52	39	48	55

*Known to be open to error because stigmas are receptive before anthesis and may be receptive for as long as 10 days after the anther column has disintegrated.

**Dwarfs were all less than 2" transverse diameter, low in seed count, and red-ripe when recorded in late season.

that the best results of the period in terms of marketable fruits are those from flowers reaching anthesis on March 26 and 27, this occurring after March 25 had been very dark and wet, with a rainfall total of 1.39".

The data shown in Table 2 are from plants that had been pre-conditioned to cold. There are, to be sure, good reasons from many observations to consider that the fruit-set problem involves physiological responses of complex nature that may be triggered by sharp changes in environmental conditions, including a brief chilling following weeks of moderate or favorable temperatures. With this in mind, tagging of flowers has been done on the same variety during both seasons elapsed since the data shown in Table 2 were recorded. Of 600 tags applied to flowers, 100 per day, during the fall-crop season, only 121 could ever be found; and the crop was struck by blossom-end rot during the critical period, so no useful data were obtained. During the spring-crop season of 1963 many tags were applied to flowers of Homestead 24, but not many were timed properly with forthcoming weather to add to information on the subject.

However, on the morning of April 15 the temperature suddenly dropped to 46° F. after the crop had been developing under favorable temperatures for more than 3 weeks. The plants of Homestead 24 were supporting a good load of fruits and were showing a very heavy crop of young flowers at the time; but there had been no rain for 4 weeks to wash away spray residues, and it was considered that the plants were on the verge of nutritional imbalance. Numerous flowers were tagged under dates of April 15, 16, and 17. For those dated April 15, the percent to set fruit was 46, good enough for the variety. For those dated April 16 and 17, however, the percent to set fruit was only 12; and these flowers were dropping rapidly on April 18, with the plants showing by twisting, drooping, and chlorosis of leaves that they had suffered a severe physiological shock. The latter is explainable only by the 46° F. temperature on April 15; and the mode of action is not understood but is judged to be nutritional, possibly involving excessive residues of spray chemicals.

Discussion

Tomato has been used for more basic physiological studies, perhaps, than any other crop plant. It has been the subject of numerous studies in the Phytotron at Pasadena during the past 20 years that have furnished valuable critical data on effects of temperature and light on fruit set. None of these studies, however, has shown how humidity interacts with temperature and light in connection with the fruit-set problem. The only possible interpretation of the mass of conflicting observations on the subject in Florida is that the humidity factor is frequently very important. And the only possible interpretation of its omission from the controlled-environment studies is that operation of high and low humidities brings-up serious difficulties of more than one kind. For an example of biological nature, at high humidity and low temperature, Botrytis gray mold would be mighty hard to control. It is the writers opinion, however, that we shall not be able to arrive at a satisfactory understanding of this costly and challenging problem of fruit-set until the interactions between temperature, humidity, and light have been determined. Once this is done, it should not then be especially difficult to ascertain what part minor-element nutrition may play in fruit-set.

The surprising observation that poor pollination in the 1963 trials at Ft. Pierce fits with the occurrence of abnormal low humidity in conjunction with low temperature, of course calls for many more careful observations. It may make good sense, in the end, despite the long-established idea that excessive humidity had been the crux of the problem. It may require some study of damage by blowing sand to the stigmatic surfaces of tomato flowers and possible adjustments in tomato culture.

Approach to the Problem in Tomato Breeding

Our main approach to this problem to date in Florida is concomitant with all other major objectives in the tomato-breeding project. In our efforts to develop improved tomatoes it is normal procedure to select for further observation those lines and single plants that make the earliest and highest yields. It thus amounts to natural selection that would be operative if no thought were given to the pollination problem and its ramifications. In everyday practice, those plants are selected that are best in production of shapely, full-sized fruits. These selections are, under normal procedure, checked and sorted for performance through several seasons in 3 or more locations in the State before they are considered candidates as new varieties. In general, it turns out that a selection that sets fruit at a slightly higher temperature also sets at a slightly lower temperature. There appears to be no doubt that progress is being made in the selection of stocks that are improved in dependability for fruit-set over an ever-broadening range of conditions.

LITERATURE CITED

1. Curme, J. H. Effect of low night temperature on tomato fruit set. Proc. Plant Sci. Symposium, Campbell Soup Co., Camden, N. J., 1962.
2. Schneck, H. W. Pollination of greenhouse tomatoes. Bul. 470, Cornell Univ. Agr. Expt. Sta., Ithaca, N. Y., 1928.
3. Young, P. A. Why tomato flowers fail to set fruits. Journal of the Rio Grande Valley Horticultural Society 9:103-104. 1957.

SOME EFFECTS OF NITROGEN SOURCE ON BEANS AND PEPPERS GROWING IN ROOT-KNOT INFESTED SOIL[1]

J. A. Winchester and H. Y. Ozaki[2]

The root-knot nematodes (*Meloidogyne incognita acrita* and *M. arenaria*) are the cause of primary nematode problems of crops on the sandy soils of Florida, and their control has been a major expense to growers. While several nematocides give good control, their cost may be considered uneconomical for some crops. A crop rotation program has been devised (10, 11) which includes pangolagrass for the control of root-knot nematodes. A minimum of one year in pangolagrass is essential for best results.

Studies have been conducted in other areas on the effect of organic matter on nematodes. Linford *et al.* (4) found that root-knot nematode populations were reduced during the decomposition of chopped pineapple plants in Hawaii. Watson (9), in 1941, recommended organic mulches for root-knot control in Florida and suggested that dead grasses, weeds, and leaves piled on the ground were excellent for this purpose. Mature dried crop residues of a number of crops including corn, oat straw, lespedeza hay, soybean hay, tomato, buckwheat hay, cotton, and red clover hay were applied by Johnson (1) to reduce root-knot galling on tomatoes. Better control was obtained after 30 weeks than after shorter periods. A 95 percent reduction of galls was obtained with lespedeza hay treated soil after 30 weeks.

Lear (3) found that castor pomace reduced populations of *Heterodera schachtii* and *M. ja-*

[1]Fla. Agr. Exp. Sta. Journal Series No. 1761.
[2]Assistant Nematologist, Everglades Experiment Station and Assistant Horticulturist, Plantation Field Laboratory, Ft. Lauderdale.