MARKETING RESEARCH REPORT

WANTING: No. 422, 430
Supplement: No. 429

SALVAGING TOMATOES FROM FROZEN VINES

Marketing Research Report No. 423

Agricultural Marketing Service
U.S. DEPARTMENT OF AGRICULTURE

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November 1960

Salvaging Tomatoes From Frozen Vines

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Highlights

Damage to tomatoes from freezing depends on the duration of temperature at or below the freezing point, the extent of vine cover, and the pattern of weather that follows. Tomatoes freeze at about 30.5° F.

Fruits with freezing injury develop a variety of symptoms. Tissues frozen throughout an area develop a water-soaked appearance when thawed. In typical freezing injury a fruit may be frozen throughout or have irregular or isolated water-soaked areas with sharp margins. Some freezing injury is so slight that the signs of damage are temporarily obscured.

Tomatoes may also be injured by low, but nonfreezing (chilling), temperatures. Fruits subjected to an average daily mean temperature below 50° F. for a week should not be shipped.

The successful marketing of tomatoes from frozen vines depends on the thoroughness with which fruits damaged by freezing are detected and discarded during harvesting and packing. Fruits that have been subjected to low field temperatures long enough to be injured by chilling must be avoided regardless of vine damage.

Tomatoes showing symptoms of freezing injury, such as water-soaked areas, pebbly or collapsed tissues, yellowing of localized areas, or a water-soaked condition in the stem scar, should be discarded.

If harvesting can be delayed for a day after the freeze and the tomatoes can be held in the packinghouse for 1 to 3 days before grading, delayed symptoms of slight freezing injury will appear and the damaged tomatoes can be identified.

[1] John T. Worthington, Cleveland Brown, William Ebersole, and Kenneth Wisner assisted in conducting the investigation.

The Problem

The winter crop of tomatoes in Florida may be particularly vulnerable to freezing damage. Winter production extends from the Tampa Bay area south. Subfreezing temperatures may occur in these tomato-producing areas from December through February. Between 1949 and 1959 at least five severe freezes occurred which caused extensive losses to tomato growers. In some locations tomato vines were only slightly damaged; in other areas they were completely killed. Freezing may be a problem in other production areas also.

After a freeze the grower must determine to what extent marketable tomatoes can be salvaged from the frozen vines. The study reported here was undertaken to aid growers in making these determinations. This study is part of a broad program of research aimed at reducing marketing costs and expanding markets for farm products.

The problem was twofold: (1) To determine the symptoms of slight freezing injury to the fruits and (2) to determine the effect of subfreezing temperatures on subsequent ripening of tomatoes that showed no freezing damage at harvest.

Procedure

The study was conducted for three seasons at Beltsville, Md., on a fall-grown crop of Rutgers tomatoes. Seeds were planted about June 10, and transplants were set in the field about July 24. The crop was timed to reach the mature-green stage about the time of the first cold wave. Usually, in this locality frosts start about October 10. At that season usually two or three frosty nights with subfreezing temperatures run in succession, interspersed with sunny days. A warm period usually follows each cold wave. This type of weather pattern is very similar to the cold waves that, at times, penetrate southern Florida and damage the tomato crop.

A thermograph and one or more thermometers that recorded maximum and minimum temperatures were placed in an instrument shelter about 8 inches above the ground. Temperatures obtained in a standard weather station shelter were used in this report because local temperature reports available to growers would be obtained under similar conditions. In 1958 maximum-minimum thermometers were also placed outside on clusters of fruits.

Mature-green tomatoes were harvested before and after frosts and were washed, graded, and placed at 65° F. to ripen. Following field temperatures below the freezing point of tomatoes, harvested fruits were examined for freezing injury, and those showing injury were discarded. During ripening further observations were made on the latent development of symptoms of freezing injury and on the relation of the injury to blemishes and decay.

What Others Have Found

Earlier research in the Department of Agriculture showed that leaves of tomato plants in the field froze at about 30.2° F., stems at about 30.0°, and fruits, either on or off the plant, at about 30.5°.[2] No substantial difference was found in the freezing points of 19 varieties.

The freezing point of a fruit is generally considered as the internal temperature at which ice crystals begin to form in the tissues. Harvested fruits, subjected to subfreezing temperatures, frequently cool below the true freezing point before the tissues freeze. This is referred to as undercooling. In the earlier research no undercooling was noted of tomatoes frozen on the vines. The freezing dew on the surface of the tomatoes probably stimulated prompt freezing and thus undercooling was prevented. The temperature on the exposed upper surface of tomatoes was lower than surrounding air because of the rapid radiation of heat from the tomato surface.

[2] Harvey, R. B., and Wright, R. C. Frost Injury to Tomatoes. U.S. Dept. Agr. Bul. 1099, 10 pp. 1922. (Out of print.)

Symptoms of Freezing Injury

Because of variations in fruit exposure, freezing injury in the field ranges from entire fruits to those that escape injury. Freezing damage occurs on the exposed upper surface of the tomato where radiation of heat is greatest. Because the position of fruits on the vine varies, freezing injury can occur on any part of the tomato. For convenience in considering symptoms the range of freezing injury is discussed in two general categories—visible and obscured freezing injury.

Visible Freezing Injury

This category includes fruits that show definite signs of damage immediately after the freeze. The injury can be detected by the presence of frozen or water-soaked tissues. The frozen tissues are killed throughout. When the ice crystals between the cells melt, the damaged areas are water-soaked (fig. 1). The extent and pattern of damage may vary greatly. Although the sheltered half of the fruit usually escapes freezing, the most exposed fruits may be completely frozen.

Typical freezing injury is characterized by irregular water-soaked spots with sharp margins. If small areas of tissues are killed, the tissues become uniformly sunken, when the frozen areas thaw. If the damaged areas are large, the tissues collapse and become soft. Decay invariably follows; soft-rot organisms usually cause the decay.

Some areas on the tomatoes may be seriously damaged, but the tissues not frozen throughout. After the tomatoes have thawed, the

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FIGURE 1.—Typical, severe freezing injury. Water-soaked condition visible as soon as tissues thaw.

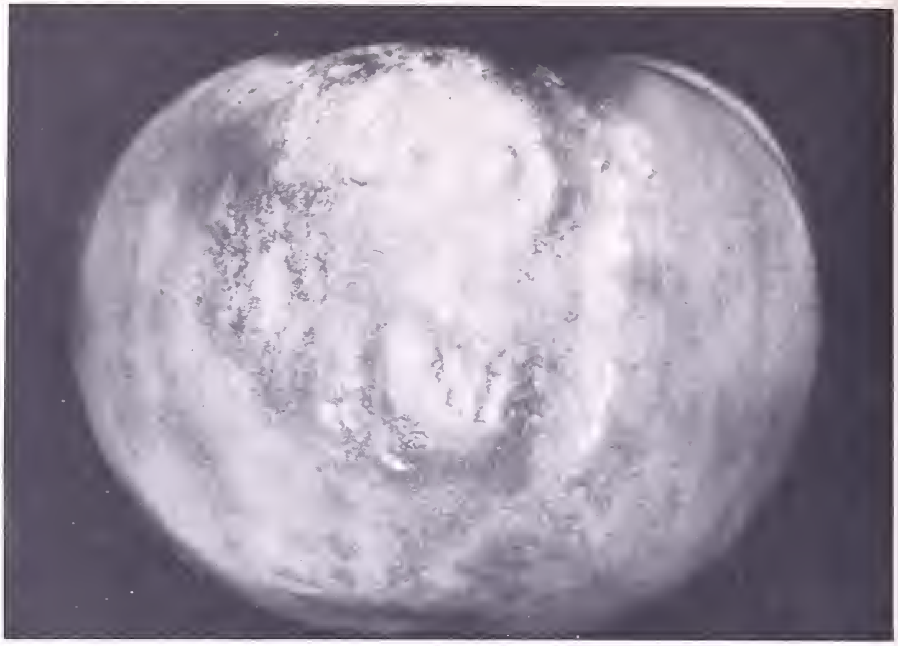

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FIGURE 2.—Water-soaked areas are first signs of freezing, but they gradually disappear. Following bright, sunny weather, affected area becomes roughened, somewhat bleached, and irregularly sunken.

affected spots are water-soaked and the adjacent tissues appear normal. Gradually, the affected area becomes rough and somewhat bleached, and the tissues are irregularly sunken (fig. 2).

Fruits that are visibly frozen can be easily recognized and discarded at harvest.

Obscured Freezing Injury

Freezing injury that is not visible immediately after the frost poses a real problem for the grower and packer when they sort the tomatoes. In such fruits frozen and normal tissues are intermingled; and when the ice crystals melt, the injured tissues tend to recover because of the presence of normal tissues.

A variety of symptoms appears on fruits if the tissues are only slightly or moderately frozen. The damaged tissues usually become dry and somewhat bleached. If damage is extensive, the injured tissues gradually collapse and become sunken. Sunlight hastens the collapse. If bright sunshine follows the freeze, some damage is evident within 24 hours after the freeze. If damage is less extensive, fruits gradually develop a pebbly surface over the affected area (fig. 3). This symptom may develop in 1 to 4 days.

One of the striking symptoms of slight and moderate freezing injury is a yellowish color that develops over the damaged area. This color change seems to be induced by sunshine and usually is apparent in 1 or 2 days. Yellowing is a useful symptom because it is easily recognized and also because it is present on fruits damaged too slightly to show collapsed tissues.

Occasionally fruits may show no external evidence of damage but have a small dry spot on the seeds and jellylike material around them (fig. 4).

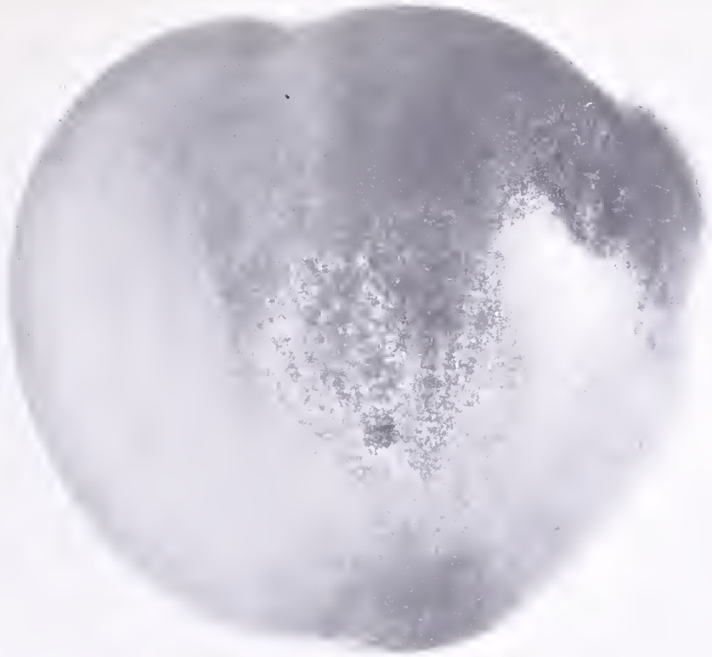

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FIGURE 3.—Delayed symptoms of freezing injury. Yellowish color, pebbly surface, and drying of affected tissues are hastened by sunlight and require one or more days to develop.

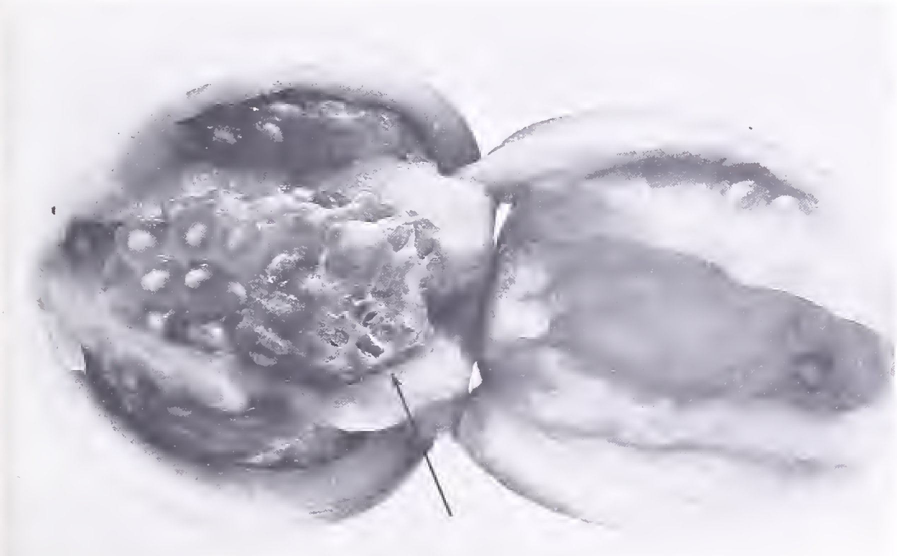

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FIGURE 4.—Obscured freezing injury may have slight yellowing of affected area or may show no external symptoms. Note dry spot in seed cavity.

The effects of duration of subfreezing temperatures on subsequent ripening of tomatoes is discussed separately for each of the 3 years because of variable weather conditions.

1956

Studies were made on the ripening of mature-green tomatoes harvested September 26 and October 10, 11, and 12 (table 1).

On the morning of September 21, an unseasonable drop in temperature occurred. A minimum of 30.5° F. was recorded for about a half hour in the weather shelter. Although the air temperature around the vines was somewhat lower than 30.5°, the duration was so brief that only the tops of the vines were frosted, and there was no apparent damage to the fruit. Moderate weather then prevailed, and a test lot of fruits was harvested September 26 and ripened at 65°.

A second harvest was made October 10, without additional frost, and the fruits were ripened at 65°. Fruits from these two harvests ripened normally.

The first killing frost occurred on the morning of October 11. The temperature in the instrument shelter was below 30° F. for about 2½ hours and the minimum was about 29°. The cold penetrated deeply into the vines, and only a few lower leaves and branches remained unfrozen. All of the most exposed fruits showed water-soaked areas typical of definite freezing injury. Test lots of tomatoes were harvested the afternoon of October 11. The fruits selected for the ripening test showed no signs of freezing injury. After 2 days of ripening at 65° the fruits were examined for new signs of freezing damage. In this test about three-fourths of the fruits that developed symptoms of freezing injury during

TABLE 1.—*Ripening of tomatoes harvested after light and heavy frosts in 1956* [1]

Date of harvest and weather conditions during previous 24 hours	Ripened normal and sound [2]	Freezing injury cumulative after holding at 65° F.		Decay	
		2 days	Until ripe	In area injured by freezing	Independent of freezing injury
September 26, 1956	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
30.5° F. for ½ hour; light frost	99	0	0	0	1
October 10, 1956					
34° for 2 hours; no frost	100	0	0	0	0
October 11, 1956					
29° for 2½ hours; killing frost	87	9	13	4	0
October 12, 1956					
Below 30° for 5 hours, low of 28°; heavy frost	91	5	7	2	2

[1] Total tomatoes in a test ranged from 64 to 166.
[2] The percentage of fruits ripened normal and sound, those showing freezing injury when ripe, and those with decay independent of freezing injury equals 100 percent.

ripening showed the symptoms after 2 days at 65°. Losses during ripening were not extensive.

The final harvest was made the afternoon of October 12 after another hard freeze. The temperature was below 30° F. for 4½ hours with a minimum of 28°. Because the vines were killed by the previous freeze, there was little to protect the fruits. Even with vines from which fruit had not previously been picked, it was difficult to find mature-green fruits that were not visibly frozen. As a result of careful sorting of those harvested, however, a high percentage of test fruits ripened normally (table 1).

From 87 to 91 percent of the mature-green tomatoes showing no signs of freezing injury at harvest were successfully ripened after the vines were frozen. Fall temperatures were favorable for fruit development. Field chilling before the freezes was not a problem.[3] Holding the tomatoes 2 days at 65° F. before grading was helpful in sorting out fruits affected by slight freezing injury. Some damaged fruits escaped detection, however.

1957

Daily mean temperatures ranged between 80.5° and 65° F. from September 1 to 24. Although minimum temperatures dropped between September 24 and October 11, the average daily mean (55.9°) remained high enough to permit normal function of the plants.

On October 12 the temperature dropped to 30° F. in the instrument shelter for a brief time, and slight freezing damage occurred to the tops of the vines. No freezing injury was visible on fruits harvested the afternoon of October 12. The fruits ripened normally; only one tomato developed symptoms of slight freezing injury; and one other developed decay (table 2).

The second frost occurred on October 13. The temperature was 30° F. or below for about 5 hours with a minimum of 28° which lasted about one hour. The maximum on October 13 was 58°, followed by a minimum of 32° during the early morning of October 14. Test lots were harvested the afternoon of October 14. Various degrees of freezing injury were observed on the most exposed fruits in the field. Sheltered fruits that appeared uninjured were readily found, however, and ripened with little loss (table 2).

A third harvest was made October 21. The vines were killed by the freeze of October 13, and one or two slight freezes occurred between the second and third harvest. Carefully sorted tomatoes developed only 7.0 percent culls during ripening because of slight freezing injury in the field and 3.0 percent decay (table 2).

Between October 21 and 30, freezes of varying degrees occurred. Although the vines were killed by the freeze of October 13, two additional harvests were made to study ripening of tomatoes exposed to such adverse conditions. The average daily mean temperature between October 12 and 30, was 49.0° F., and field chilling became a problem by October 25 and 29, dates of the last harvests. In these tests there was a sharp increase in fruits that developed symptoms of freezing injury during ripening. Serious chilling injury was also noted during ripening; this injury caused black scars and the occurrence of alternaria rot (*Alternaria tenuis* auct.) on a large percentage of fruits.[4]

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[3] McColloch, Lacy P. Effect of Low Field Temperatures on Quality of Tomatoes. Fla. State Hort. Soc., Proc. 68: 188–192. 1955.

Morris, L. L. Field and Transit Chilling of Fall-Grown Tomatoes. Conf. Transportation of Perishables, Proc., Davis, Calif., April 26–28, 1954.

[4] McColloch, L. P. *Alternaria tenuis* the Cause of a Tomato Fruit Rot. Plant Dis. Rptr. 35: 234–236. 1951.

TABLE 2.—*Ripening of tomatoes harvested after light and heavy frosts in 1957* [1]

Date of harvest and previous weather conditions	Ripened normal and sound [2]	Freezing injury found after holding at 65° F. until ripe	Decay	
			At area injured by freezing	Independent of freezing injury
October 12, 1957				
	Percent	*Percent*	*Percent*	*Percent*
30° F. for ½ hour; light frost	98	1	0	1
October 14, 1957				
28° F. for 1 hour, below 30° 5 hours, heavy frost	96	3	0	1
October 21, 1957				
Slight additional freezes	90	7	1	3
October 25, 1957				
Slight additional freezes	49	12	0	39
October 29, 1957				
Slight additional freezes	45	21	2	34

[1] Total tomatoes in a test ranged from 106 to 244.
[2] The percentage of fruits ripened normal and sound, those showing freezing injury when ripe, and those with decay independent of freezing injury equals 100 percent.

Fall weather in 1957 was favorable to tomato development until October 13, when the vines were frozen. Mature-green tomatoes, showing no signs of freezing damage when harvested October 12, 14, and 21 following various periods of subfreezing weather, ripened with only 2 to 10 percent loss. The average daily mean after the first killing frost of October 13 was conducive to chilling injury. Fruits harvested October 25 and 29 were seriously affected and developed extensive alternaria rot in addition to an increase in delayed symptoms of freezing injury.

1958

Weather conditions in 1958 afforded a study of tomato ripening after a slight freeze on October 6, repeated slight freezes between October 27 and November 7, and a severe freeze on November 8 (table 3).

In 1958 temperatures were obtained in the open to compare with those in the instrument shelter. A thermometer that recorded maximum and minimum temperatures was placed in a horizontal position on the vine about 8 inches above the soil. A similar instrument was placed in a comparable position in the instrument shelter. The outside thermometer, fully exposed to radiation, registered 2 to 5 degrees lower than the one in the shelter (table 4). Temperature on the exposed thermometer is comparable to the temperature on the upper surface of a fully exposed tomato.

The light frost of October 6 caused no freezing damage to the fruits (table 3). Ripening was normal, and only 1 percent were discarded because of decay.

Table 3.—*Ripening of tomatoes harvested following light and heavy frosts in 1958* [1]

Date of harvest and previous weather conditions	Ripened normal and sound [2]	Freezing injury found after holding at 65° F.		Decay	
		2 days	Until ripe	At area injured by freezing	Independent of freezing injury
October 6, 1958	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
31° F.; light frost	99	0	0	0	1
November 7, 1958					
Several light frosts	88	--------	7	4	5
November 8, 1958					
Minimum 22.5° F.; below 30° for 9 hours	79	12	16	10	5

[1] Total tomatoes in a test ranged from 70 to 292.
[2] The percentage of fruits ripened normal and sound, those showing freezing injury when ripe, and those with decay independent of freezing injury equals 100 percent.

Table 4.—*Comparison of minimum temperatures in instrument shelter and on exposed vine, 1958*

Date	In instrument shelter	On vine	Date	In instrument shelter	On vine
	° F.	*° F.*		*° F.*	*° F.*
Oct. 27	31. 5	29. 0	Nov. 5	32. 0	27. 5
29	39. 5	35. 0	7	40. 0	35. 5
30	34. 0	28. 0	8	26. 0	22. 5
Nov. 3	31. 0	28. 5	10	30. 5	27. 0
4	30. 0	28. 0	11	28. 0	25. 5

A series of light frosts, interspersed in a long period of moderate weather, damaged but did not kill the vines. No visible freezing injury to the fruits was found, although at each brief cold period the temperature, registered on the thermometer placed on the vine, dropped below the freezing point of tomatoes. It was thought that the series of low night temperatures were too brief to cause chilling injury. The fruits were adversely affected, however. Those harvested November 7 were very loosely attached at the first stemnode and were nearly ready to drop from the vine. The fruits were also abnormally soft. Although no freezing injury was apparent at harvest, 7 percent of the test fruits developed symptoms of slight freezing injury during ripening at 65° F. (table 3). Losses from freezing injury and decay were 12 percent.

A cold wave starting November 7 depressed the temperature to 30° F. by 10:00 p.m. and to a minimum of 26°. The temperature was 30° or below for 9 hours. This was the longest and most severe freeze experienced during the 3 years of tests. The vines were killed, and about 80 percent of the fruits were visibly frozen. Fruits from sheltered parts of the vines were harvested the afternoon of November 8 and ripened. These fruits showed no signs of freezing injury at harvest. After 2 days at 65°, 12 percent showed signs of freezing injury. During the ripening period symptoms of freezing injury increased to 16 percent.

Damaged fruits were disfigured and about two-thirds of them developed decay. Losses from freezing injury and decay were about 21 percent of the fruits in test.

Fall weather in 1958 was favorable to the tomato crop until October 6. Between that date and October 27, the temperature fluctuated greatly. Twelve nights of freezing or near freezing temperatures were interspersed with periods of bright, sunny weather which prevented definite chilling injury. During the period described above, however, a moderately small amount of hidden freezing damage occurred and became evident during ripening.

The feasibility of harvesting tomatoes following a freeze of the proportions of that of November 8, 1958, in which 80 percent of the fruits were visibly damaged, depends on the market supply. Successful ripening and marketing depend upon the degree to which tomatoes damaged by freezing are detected during careful sorting.

Appendix

Table 5.—*Maximum, minimum, and average air temperatures recorded in the field in a standard weather station shelter, 1956*

Date	Maximum	Minimum	Mean	Date	Maximum	Minimum	Mean
Sept. 1	93	67	80. 0	Sept. 22	65	40	52. 5
2	93	67	80. 0	23	73	47	60. 0
3	87	65	76. 0	24	88	60	74. 0
4	83	61	72. 0	25	69	43	56. 0
5	86	63	74. 5	26	70	51	60. 5
6	85	67	76. 0	27	63	45	54. 0
7	84	66	75. 0	28	54	48	51. 0
8	73	48	60. 0	29	57	51	54. 0
9	71	46	58. 5	30	64	55	59. 5
10	68	38	53. 0	Oct. 1	74	31	52. 5
11	70	46	58. 0	2	70	43	56. 5
12	77	50	63. 5	3	75	49	62. 0
13	81	54	67. 5	4	79	57	68. 0
14	88	57	72. 5	5	69	53	61. 0
15	90	65	77. 5	6	71	46	58. 5
16	75	59	67. 0	7	63	54	58. 5
17	85	59	77. 0	8	67	34	50. 5
18	87	46	66. 5	9	69	39	54. 0
19	70	43	56. 5	10	70	34	52. 0
20	72	50	61. 0	11	58	29	43. 5
21	63	31	47. 0	12	60	30	45. 0

Table 6.—*Maximum, minimum, and average air temperatures recorded in the field in a standard weather station shelter, 1957*

Date	Maximum	Minimum	Mean	Date	Maximum	Minimum	Mean
Sept. 1	87. 0	67. 0	77. 0	Oct. 1	64. 0	48. 0	56. 0
2	85. 0	60. 0	72. 5	2	68. 0	50. 0	59. 0
3	88. 0	73. 0	80. 5	3	72. 0	43. 0	57. 5
4	92. 0	68. 0	80. 0	4	65. 0	39. 0	52. 0
5	88. 0	52. 0	70. 0	5	66. 0	43. 0	54. 5
6	79. 0	51. 0	65. 0	6	64. 0	49. 0	56. 5
7	77. 0	57. 0	67. 0	7	60. 0	43. 0	51. 5
8	78. 0	62. 0	70. 0	8	69. 0	52. 0	60. 5
9	76. 0	61. 0	68. 5	9	67. 0	55. 0	61. 0
10	71. 0	62. 0	66. 5	10	74. 0	46. 0	60. 0
11	85. 0	64. 0	74. 5	11	69. 0	38. 0	53. 5
12	81. 0	65. 0	73. 0	12	57. 0	30. 0	43. 5
13	90. 0	63. 0	76. 5	13	58. 0	28. 0	43. 0
14	90. 0	68. 0	79. 0	14	66. 0	30. 0	48. 0
15	85. 0	66. 0	75. 5	15	69. 0	33. 0	51. 0
16	88. 0	67. 0	77. 5	16	69. 0	37. 0	53. 0
17	86. 0	65. 0	75. 5	17	68. 0	43. 0	55. 5
18	75. 0	61. 0	68. 0	18	65. 0	53. 0	59. 0
19	75 0	62. 0	68. 5	19	63. 0	47. 0	55. 0
20	79. 0	55. 0	67. 0	20	55. 0	39. 0	47. 0
21	77. 0	63. 0	70. 0	21	63. 0	32. 0	52. 5
22	86. 0	71. 0	78. 5	22	65. 0	33. 0	49. 0
23	88. 0	64. 0	76. 0	23	67. 0	34. 0	50. 5
24	71. 0	47. 0	59. 0	24	72. 0	46. 0	59. 0
25	68. 0	40. 0	54. 0	25	63. 0	49. 0	56. 0
26	75. 0	49. 0	62. 0	26	54. 0	31. 0	42. 5
27	78. 0	34. 0	56. 0	27	48. 0	32. 0	40. 0
28	62. 0	35. 0	48. 5	28	47. 0	32. 0	39. 5
29	62. 0	41. 0	51. 5	29	51. 0	30. 0	40. 5
30	58. 0	47. 0	52. 5	30	63. 0	35. 0	54. 0
				31	58. 0	37. 0	47. 5

Table 7.—*Maximum, minimum, and average air temperatures recorded in the field in a standard weather station shelter, 1958*

Date	Maximum	Minimum	Mean	Date	Maximum	Minimum	Mean
Oct. 1	74. 0	45. 0	59. 5	Oct. 21	65. 0	46. 0	55. 5
2	62. 0	41. 0	51. 5	22	59. 0	47. 0	53. 0
3	61. 0	51. 0	56. 0	23	63. 0	56. 0	59. 5
4	58. 0	54. 0	56. 0	24	70. 0	50. 0	60. 0
5	72. 0	41. 0	56. 5	25	76. 0	41. 0	58. 5
6	58. 0	31. 0	44. 5	26	62. 0	45. 0	53. 5
7	68. 0	33. 0	50. 5	27	53. 0	31. 0	42. 0
8	70. 0	34. 0	52. 0	28	58. 0	43. 0	50. 5
9	80. 0	44. 0	62. 0	29	64. 0	39. 5	51. 7
10	86. 0	52. 0	69. 0	30	66. 0	34. 0	50. 0
11	85. 0	39. 0	62. 0	31	65. 0	31. 0	48. 0
12	68. 5	38. 0	53. 0	Nov. 1	70. 0	32. 0	51. 0
13	63. 0	35. 0	49. 0	2	65. 0	42. 0	53. 5
14	61. 0	36. 0	48. 5	3	46. 0	31. 8	38. 9
15	60 0	42. 0	51. 0	4	58. 0	30. 0	44. 0
16	82. 0	45. 0	63. 5	5	62 0	32. 0	47. 0
17	83. 0	48. 5	65. 8	6	60. 0	38. 0	49. 0
18	82. 0	43. 0	62. 5	7	57. 5	40. 0	48. 8
19	68. 0	37. 0	52. 5	8	53. 0	26. 0	39. 5
20	62. 0	37. 0	49. 5				

U.S. GOVERNMENT PRINTING OFFICE: 1960 O—560698