STHARVEST WEIGHT LOSS AND SHRIVEL IN FIVE FRUITS AND FIVE VEGETABLES

Marketing Research Report No. 1059

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

U.S. Department of Agriculture marketing research is part of a continuing program to reduce marketing losses and to extend the marketing season of agricultural products. This study was undertaken to develop information to aid in alerting produce handlers to a major cause of deterioration (moisture loss with shriveling) in fresh fruits and vegetables during handling, transportation, storage, and packaging.

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Washington, D.C. Issued February 1977

POSTHARVEST WEIGHT LOSS AND SHRIVEL IN FIVE FRUITS AND FIVE VEGETABLES

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SUMMARY

Weight loss and shrivel severity were determined on over 2,000 freshly harvested individual specimens of five fruits and five vegetables grown in 1972, 1973, and 1974 at or near Beltsville, Md. Test produce items were individually weighed and then exposed in a single layer with each specimen well separated from adjacent specimens in a room averaging 75° F (24° C) and 25 percent relative humidity. Apples and pears also were held at 32° (0°) and 95 percent relative humidity. Weight losses required to shrivel each specimen varied with, and especially within, each kind of produce. These losses were higher than losses published by others.

Trace and slight shrivel symptoms, while noted by the researcher, had little effect on acceptable commercial appearance. Moderate, severe, and extremely severe shrivel progressively damaged commercial appearance. At 75° F, apples, nectarines, peaches, pears, and persimmons showed moderate shrivel, with percent weight losses averaging 10, 21, 16, 9, and 11, respectively. Snap beans, early cabbage heads, sweet peppers, summer squash, and firm ripe tomatoes showed moderate shrivel with percent weight losses averaging 41, 11, 12, 24, and 6, respectively. Rate of weight losses also varied markedly. Average percent weight losses per day at 75° and 25 percent relative humidity for the five fruits were: Apples (0.5), nectarines (1.4), peaches (2.8), pears (0.7), and persimmons (1.9). Average percent weight losses per day for the five vegetables were: Beans (10.2), cabbage (1.3), peppers (2.2), squash (2.3), and tomatoes (0.5).

Before any symptoms were noted, percent weight losses in individual snap beans ranged from 12 to 64, averaging 32, and in nectarines ranged from 10 to 21, averaging 16. After 2 days' holding at 75° F, percent weight losses in snap beans ranged from 14 to 53, averaging 29. After 7 days, losses in peaches ranged from 11 to 27 percent, averaging 20. Weight losses were lower in other fruits and vegetables tested but variability was wide. Weight loss causes not only a direct quantitative monetary loss because produce is often sold by the pound, but also causes a qualitative loss in appearance and thus salability. Weight loss can cause nutritional loss involving flavor and vitamins.

INTRODUCTION

Weight loss, due to water loss from fresh produce, has many reported effects—physical, physiological, pathological, nutritional, economic, and esthetic. Thus weight loss is reported to change specific gravity slightly in Irish potatoes (*17*),[1] hasten ripening in fruits (*1, 13*), reduce decay in lettuce (*3*), increase decay in carrots (*18*), reduce vitamin C and

[1] Italic numbers in parentheses refer to Literature Cited, p. 23.

carotene in kale (*4, 5*), reduce salable weight and economic value in produce in general (*12, 14*), and mar appearance in most fruits and vegetables by wilt and shrivel (*12, 14*).

During 1972 in an unpublished store survey, 20 consumer units of snap beans, bought at 10 supermarkets near the Beltsville Agricultural Research Center, contained 0 to 33 percent objectionably shriveled beans. The produce managers did not know how much weight had been lost from these or other produce items.

Shrivel symptoms have been linked with weight losses ranging from 3 to 6 percent (*2, 8, 11, 14, 15*). At weight losses over 10 percent, severe wilt was noted in most kinds of bulk fruits and vegetables (*16*). However, a few commodities may lose more than 10 percent weight and remain marketable, with trimming needed in some cases (*14*). In some tests, weight losses of 15 percent (*10*) or 10 to 23 percent (*2, 6, 7*) occurred before wilt was noticeable or shelf life was ended.

The observation of 15 percent weight loss without shrivel symptoms suggested that some estimates of shrivel-producing weight loss may have been too low. The observation also suggested the need for more data on weight loss from fruits and vegetables to alert produce handlers.

This report deals with the amounts of salable weight loss from each of five fruits and five vegetables when each of six degrees of shrivel becomes visible. Weight loss data were collected from produce exposed in a single layer. Thus rates of weight loss reported may be comparable to weight loss rate from surface layers of commercial containers. Good packaging, handling, and marketing practices can materially lower these weight loss rates (*2, 3, 6, 7, 8, 10, 11, 12, 14, 15, 16, 18*).

METHODS AND MATERIALS

At Beltsville, Md., from September 1972 to December 1974, weight loss and shrivel data were collected on over 2,000 individual specimens of freshly harvested nonwaxed fruits and vegetables. The produce items were grown at Beltsville Agricultural Research Center—West or nearby farms. Fruits tested were 640 apples (320 at each of two temperatures), 100 nectarines, 150 peaches, 320 pears (160 at each of two temperatures), and 70 persimmons. Vegetables tested were 400 snap beans, 20 heads and 30 jacket leaves of early cabbage, 200 sweet peppers, 100 summer squash, and 140 firm ripe tomatoes. Each commodity was harvested when it was suitable for immediate preparation and consumption or commercial storage. Initial weights and observations were taken on the day of harvest, generally within 1 hour of harvest, except for nectarines which were initially weighed and observed the day after harvest. All weights were determined to one hundredth of a gram. Each weight was of an individual fruit, pod, leaf, or head.

Following initial weighing and observation, most groups within each of the 10 fruits and vegetables were placed in a single layer with each individual specimen well separated from adjacent specimens on trays in a room held at about 75° F (24° C) and 25 percent relative humidity. Room conditions during holding ranged from 70° to 80° and 20 to 30 percent relative humidity. In addition, groups of apples and pears were also held at 32° (0°) and 95 percent relative humidity ranging from 31° to 33° and 90 to 99+ percent, respectively. Some apples were stored 4 months in polyethylene-lined boxes before holding on trays at 75° or 32°. Subsequent weighings and examinations of each individual specimen for shrivel symptoms were done in each holding room (75° or 32°) to avoid weight changes caused by moisture condensation which often occurs on produce when moved to a warmer temperature. The subsequent weighings of each specimen were done at frequent intervals so a fairly good estimate could be made of the maximum weight loss occurring before any symptom was evident (zero) and of the minimum percent weight losses associated with the onset of each of five degrees of shrivel (trace, slight, moderate, severe, and extremely severe).

When applicable, data were processed by analysis of variance and Duncan's multiple-range test at the 5-percent level of statistical

significance (*9*). Data for each kind of fruit and vegetable were analyzed separately. Duncan multiple-range test letters thus apply only to differences within each kind and not between kinds of fruit or vegetable.

No shrivel (zero) denotes field-fresh condition with no visible wrinkling. For example, on an apple with a shrivel rating of "zero," no visible wrinkling is produced by light thumb and finger pressure. *Trace shrivel* shows no visible wrinkling without pressure. Wrinkling, however, can be produced by light pressure, but this wrinkling disappears when pressure is discontinued. There is some loss of turgidity without visible wrinkling. *Slight shrivel* is a barely visible wrinkling on produce surface and is visible without pressure. None of the first three symptoms is serious enough to affect commercial appearance. *Moderate shrivel* is plainly visible wrinkling which detracts from commercial appearance. *Severe shrivel* is deeper more obviously visible wrinkling which seriously detracts from commercial appearance. *Extremely severe* shrivel is very bad wrinkling, accompanied by stiff dry texture in some commodities, such as green beans or cabbage. Such shrivel very seriously detracts from commercial appearance.

WEIGHT LOSS TESTS

In all produce tested, whether held at 75° F (24° C) and 25 percent relative humidity or at 32° (0°) and 95 percent relative humidity, weight loss rate and weight loss required for onset of shrivel symptoms varied widely, within each replicate of fruit or vegetable, each cultivar, each holding room, each time period, and each symptom class. Weight loss and shrivel data for fruits are reported in table 1 and for vegetables in table 2.

Fruits

Apples

A total of 640 freshly harvested apples in groups of 20 from each of four cultivars (Golden Delicious, Jonathan, McIntosh, and Red Delicious) were tested. Little difference, in weight loss after various holding periods, was noted between fruit held naked immediately after harvest and fruit first stored for 4 months at 32° F in polyethylene-lined boxes before holding them naked on open trays. Therefore, these values were combined in analyzing the data.

After 4 months' storage in polyethylene-lined boxes at 32° F, percent weight loss in apples averaged about 2. After 1 week naked at 75° and 25 percent relative humidity, percent weight loss in Golden Delicious apples ranged from 1 to 9, averaging 6, and in McIntosh apples from 1 to 13, averaging 5 (table 1). Naked apples from the four cultivars lost weight at an average rate of 0.5 percent per day. In an overview of the four cultivars, percent weight loss required to produce slight shrivel symptoms ranged from 5 to 14, averaging 9 at 75°, and 2 to 13, averaging 7 at 32°. Typical shrivel symptoms in cv. Golden Delicious are shown in figure 1. At 75° and 32°, weight loss required to produce moderate shrivel symptoms, that is, shrivel serious enough to affect commercial appearance, averaged 10 and 8 percent, respectively.

Throughout the symptom range, the average weight loss required to produce symptoms was higher in apples held at 75° F than in apples held at 32°, ranging from 1 percentage point higher at trace (7 vs. 6) to 3 percentage points higher at extremely severe (12 vs. 9). Stated another way, apples at 75° were more resistant to shriveling than apples at 32°. However, apples shriveled faster at 75° than 32°. Thus during 1, 2, and 3 weeks at 75°, apples lost 5, 8, and 10 percent weight, respectively, while during 4, 8, and 12 weeks at 32° apples lost 4, 5, and 7 percent weight, respectively. Although it took more weight loss to shrivel them, the apples at 75° had lost weight at a faster rate and thus shriveled sooner than apples at 32°. The first signs of shrivel were noted in apples at 75° after 4 days to 5 weeks, averaging 3.6 weeks, and at 32° after 1 to 20 weeks, averaging 9.1 weeks.

Considered by cultivar, Red Delicious apples required most weight loss to shrivel, McIntosh and Golden Delicious apples intermediate loss to shrivel, and Jonathan apples least to shrivel. Golden Delicious apples lost weight somewhat faster than apples of the other three cultivars.

TABLE 1.—*Shrivel symptom range, percent weight loss after various holding times, and percent weight loss at onset of shrivel symptoms for 5 fruits held naked at 75° F and 25 percent relative humidity* [1]

Item	Holding time [2]			Shrivel symptom [2]					
				Zero	Trace	Slight	Moderate	Severe	Extremely severe
APPLES									
	1 week	*2 weeks*	*3 weeks*						
Golden Delicious:									
Shrivel symptom range	0	0–Ext sv	0–Ext sv						
Percent weight loss range	1–9	3–16	5–16+	3–10	4–11	5–12	7–13	7–15	8–16
Percent weight loss average.	5.7	9.4	10.7	6.5	7.3	8.4	9.4	10.5+	11.5+
Jonathan:									
Shrivel symptom range	0–S1	0–Ext sv	0–Ext sv						
Percent weight loss range	2–8	4–14	6–17	2–8	3–9	6–11	6–13	6–15	7–16
Percent weight loss average.	5.2	8.9	11.9	4.9	5.7	8.3	9.6	10.7	11.8
McIntosh:									
Shrivel symptom range	0–T	0–Ext sv	0–Ext sv						
Percent weight loss range	1–13	3–20	5–20+	3–10	3–12	6–14	7–19	8–19	8–20
Percent weight loss average.	4.6	7.5	10.4	5.5	6.3	9.2	11.2	12.3	13.3
Red Delicious:									
Shrivel symptom range	0	0–T	0–Mod						
Percent weight loss range	0.5–7	1–9	3–11	5–12	6–12	7–13	8–13	8–14	9–15
Percent weight loss average.	3.6	5.2	7.2	7.9	8.5	9.8	10.9	11.6	12.4
Four apple cultivars:									
Shrivel symptom range	0–S1	0–Ext sv	0–Ext sv						
Percent weight loss range	0.5–13	1–20	3–20+	2–12	3–12	5–14	6–19	6–19	7–20
Percent weight loss average.[3]	4.8 ab	7.8 c	10.0 d	6.2 ab	7.0 bc	8.9 e	10.3 f	11.3 g	12.2 h
	4 weeks	*8 weeks*	*12 weeks*						
Four apple cultivars at 32° F: [4]									
Shrivel symptom range	0–Ext sv	0–Ext sv	0–Ext sv						
Percent weight loss range	1–14	2–14+	2–14+	2–10	2–11	2–13	2–13	3–14	4–15
Percent weight loss average.[3]	3.8 a	5.4 b	6.7 c	5.4 a	6.1 ab	6.8 bc	7.5 cd	8.2 de	8.8 e

NECTARINES

	7 days	*10 days*	*14 days*							
Regal Grand:										
Shrivel symptom range	0–S1	0–Ext sv	0–Ext sv							
Percent weight loss range	6–21	8–29	11–34		9–21	10–21	12–23	17–26	20–29	21–32
Percent weight loss average [3].	11.6 a	16.2 b	20.1 c		14.2 a	16.1 b	18.7 c	21.2 d	23.1 e	24.8 f

PEACHES

	1 day	*4 days*	*7 days*	*10 days*						
Five peach cultivars:										
Shrivel symptom range	0	0–Ext sv	0–Ext sv	Ext sv						
Percent weight loss range	1–8	8–22	11–27	18–33	3–17	6–18	8–20	10–22	12–25	14–26
Percent weight loss average [3].	3.5 a	13.1 b	19.9 c	27.5 d	9.0 a	11.4 b	13.9 c	16.4 d	18.3 e	20.4 f

PEARS

	1 week	*2 weeks*	*3 weeks*	*4 weeks*	*8 weeks*	*12 weeks*						
Three pear cultivars:												
Shrivel symptom range	0–Ext sv	T–Ext sv										
Percent weight loss range	4–20	6–22					2–10	3–12	4–15	5–17	6–20	6–22
Percent weight loss average [3].	7.5 c	9.7 d					4.7 bc	5.8 d	7.1 ef	8.6 g	9.9 h	11.0 i
Three pear cultivars at 32°F: [4]												
Shrivel symptom range	0	0–T	0–Mod	0–Sv	0–Ext sv	T–Ext sv						
Percent weight loss range	0.6–7	0.9–8	1–10	1–10	2–18	3–20	1–9	1–10	2–11	2–13	2–15	3–17
Percent weight loss average [3].	2.4 a	3.2 ab	3.6 ab	4.3 b	7.2 c	8.1 c	3.6 a	4.1 ab	4.9 c	5.9 d	6.6 e	7.4 f

See footnotes at end of table.

TABLE 1.—*Shrivel symptom range, percent weight loss after various holding times, and percent weight loss at onset of shrivel symptoms for 5 fruits held naked at 75° F and 25 percent relative humidity* [1]—Continued

Item	Holding time [2]					Shrivel symptom [2]					
						Zero	Trace	Slight	Moderate	Severe	Extremely severe
	PERSIMMONS										
	3 days	*5 days*	*7 days*	*14 days*	*21 days*						
American (wild):											
Shrivel symptom range	0–Ext sv	0–Ext sv	0–Ext sv	-----	-----	-----	-----	-----	-----	-----	-----
Percent weight loss range	4–8	8–12	11–15	-----	-----	0.6–12	1–15	3–16	4–17	5–18	6–19
Percent weight loss average [3].	5.9 a	9.8 b	13.1 c	-----	-----	3.8 a	5.1 b	7.2 c	8.7 d	10.3 e	12.2 f
Japanese (cultivated):											
Shrivel symptom range	0	0	0	T–Ext sv	Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	2–3	4–5	5–7	11–14	15–18	6–10	7–11	8–14	9–17	10–18	11–19
Percent weight loss average [3].	2.3 a	4.0 b	6.2 c	12.4 d	16.5 e	8.3 a	9.2 b	11.0 c	13.3 d	14.4 e	15.7 f

[1] Ranges and averages for combined cultivars are each based on 320 apples, 150 peaches, and 160 pears, and for single cultivars on 100 nectarines, 60 American persimmons, and 10 Japanese persimmons. Weight loss figures are maximum losses at which no symptoms could be detected (0) and minimum losses at onset of each symptom, trace to extremely severe.

[2] Shrivel symptoms 0 = zero; T = trace; Sl = slight; Mod = moderate; Sv = severe; and Ext sv = extremely severe. Shrivel symptom range and percent weight loss range are not directly related, being derived independently and often from separate specimens. Thus minimum loss and mildest symptoms or maximum loss and most severe symptoms need not relate to same specimen.

[3] Duncan multiple range test letters for 5-percent significance level apply to significant differences between holding times or between symptom classes within each kind of produce.

[4] Data for 4 apple cultivars and 3 pear cultivars held at 32° F and 95 percent relative humidity.

TABLE 2.—*Shrivel symptom range, percent weight loss after various holding times, and percent weight loss at onset of shrivel symptoms for 5 vegetables held naked at 75° F and 25 percent relative humidity* [1]

Item	Holding time [2]						Shrivel symptom [2]					
							Zero	Trace	Slight	Moderate	Severe	Extremely severe
BEANS, SNAP												
	½ day	*1 day*	*2 days*	*3 days*	*4 days*	*5 days*						
Golden Wax (yellow broad):												
Shrivel symptom range	0	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv							
Percent weight loss range	10–18	15–32	20–52	26–62	31–69	37–83	15–44	17–46	20–51	22–59	23–69	33–83
Percent weight loss average.	12.8	21.0	35.0	46.0	52.1	58.6	23.5	28.4	32.6	37.5	41.8	52.2
Cherokee Wax (yellow pencil pod):												
Shrivel symptom range	0	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv						
Percent weight loss range	10–17	14–33	19–53	24–66	29–67	34–68	13–57	15–60	17–61	21–63	34–66	35–70
Percent weight loss average.	12.9	19.4	30.2	39.0	43.9	49.4	31.2	32.9	39.0	43.3	48.4	54.6
Bountiful (green broad):												
Shrivel symptom range	0	0–Sl	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv						
Percent weight loss range	8–16	10–27	14–47	19–61	24–68	29–71	15–57	17–64	18–65	24–68	25–70	27–72
Percent weight loss average.	11.2	15.6	26.7	36.2	43.9	49.1	32.5	39.6	44.2	47.6	50.5	55.4
Harvester (green pencil pod):												
Shrivel symptom range	0	0–Sv	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv						
Percent weight loss range	8–14	10–18	14–40	19–59	23–70	28–74	11–58	12–59	15–60	15–63	18–66	21–69
Percent weight loss average.	10.3	16.3	25.2	32.0	40.7	47.3	22.7	26.8	31.4	35.8	39.5	44.7
Four bean cultivars:												
Shrivel symptom range	0	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv						
Percent weight loss range	8–18	10–33	14–53	19–66	23–70	28–83	11–58	12–64	15–65	15–68	18–70	21–83
Percent weight loss average. [3]	11.8 a	18.0 b	29.3 c	38.3 d	45.2 e	51.1 f	27.5 a	31.9 b	36.8 c	41.0 d	45.0 e	51.7 f

See footnotes at end of table.

TABLE 2.—*Shrivel symptom range, percent weight loss after various holding times, and percent weight loss at onset of shrivel symptoms for 5 vegetables held naked at 75 ° F and 25 percent relative humidity* [1]—Continued

Item	Holding time [2]						Shrivel symptom [2]					
							Zero	Trace	Slight	Moderate	Severe	Extremely severe
CABBAGE, EARLY												
	1 day	*2 days*	*3 days*	*7 days*	*10 days*	*14 days*						
Copenhagen Market (heads):												
Shrivel symptom range	0–T	0–Sl	T–Sv	T–Sv	Sl–Ext sv	Sl–Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	2–3	4–6	5–8	8–14	11–20	14–22	1–6	2–8	4–14	6–21	7–23	11–25
Percent weight loss average.[3]	2.3 a	4.6 ab	6.6 b	11.0 c	14.9 d	17.9 e	4.0 a	5.5 b	7.3 c	10.9 d	14.6 e	18.4 f
Copenhagen Market (leaves):												
Shrivel symptom range	0–T	0–Mod	0–Sv	Sv–Ext sv	Sv–Ext sv	Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	11–31	20–49	24–54	46–86	68–82	80–88	13–36	20–42	28–52	36–63	49–79	61–85
Percent weight loss average.[3]	21.0 a	33.6 b	42.5 c	70.3 d	74.7 e	83.9 f	23.1 a	28.5 b	39.4 c	49.6 d	61.6 e	77.5 f
PEPPERS, SWEET												
	1 day	*2 days*	*3 days*	*4 days*	*5 days*	*7 days*						
California Wonder:												
Shrivel symptom range	0–T	0–Sl	0–Sv	0–Ext sv	0–Ext sv	0–Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	1–5	2–9	4–13	6–16	8–21	10–25	1–15	2–17	3–21	3–22	4–23	8–27
Percent weight loss average.[3]	2.6 a	4.6 b	7.5 c	9.9 d	12.1 e	15.1 f	6.1 a	8.1 b	10.2 c	12.2 d	13.7 e	15.4 f
SQUASH, SUMMER												
	1 day	*2 days*	*3 days*	*6 days*	*9 days*	*11 days*						
Yellow Crookneck:												
Shrivel symptom range	0–Sl	0–Mod	0–Ext sv	0–Ext sv	0–Ext sv	0–Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	2–10	3–16	4–23	6–34	8–46	9–53	5–35	7–36	7–38	9–50	10–54	10–58
Percent weight loss average.[3]	6.2 a	9.2 ab	11.5 b	17.2 c	23.0 d	25.8 d	15.0 a	17.6 b	20.2 c	23.9 d	28.0 e	31.1 f

TOMATOES, FIRM RIPE

	1 day	*2 days*	*4 days*	*6 days*	*8 days*	*14 days*						
Walter:												
Shrivel symptom range	0	0–T	0–T	0–Sv	0–Ext sv	0–Ext sv	-----	-----	-----	-----	-----	-----
Percent weight loss range	0–1	0–3	0.7–6	1–8	2–10	3–14	0.3–8	0.5–8	0.9–8	1–12	2–14	3–15
Percent weight loss average.[3]	0.6 a	1.1 a	2.2 b	3.4 c	4.1 d	6.8 f	3.5 a	4.1 b	5.0 c	6.2 d	7.1 e	8.2 f

[1] Ranges and averages for combined cultivars are each based on 400 snap beans, and for single cultivars on 20 heads of early cabbage, 200 sweet peppers, 100 summer squash, and 140 firm ripe tomatoes. Weight loss figures are maximum losses at which no symptoms could be detected (0) and minimum losses at onset of each symptom, trace to extremely severe.

[2] Shrivel symptoms 0 = zero; T = trace; Sl = slight; Mod = moderate; Sv = severe; and Ext sv = extremely severe. Shrivel symptom range and percent weight loss range are not directly related, being derived independently and often from separate specimens. Thus minimum loss and mildest symptoms or maximum loss and most severe symptoms need not relate to same specimen.

[3] Duncan multiple range test letters for 5-percent significance level apply to significant differences between holding times or between symptom classes within each kind of produce.

The first signs of shrivel were noted in the four cultivars in the following order—Golden Delicious, Jonathan, McIntosh, and Red Delicious.

Nectarines

One hundred freshly harvested nectarines cv. Regal Grand in five replicate lots of 20 each were held at 75° F and 25 percent relative humidity.

At 75° F, percent weight loss in nectarines after 1 week ranged from 6 to 21, averaging 12, and after 2 weeks ranged from 11 to 34, averaging 20 (table 1). Average weight loss rate for nectarines was 1.4 percent per day. The first signs of shrivel appeared in some nectarines after 6 days, ranging to 15 days in others. Some nectarines developed extremely severe shrivel only after 24 to 29 days at 75°. Typical shrivel symptoms for nectarines are shown in figure 2. Weight loss associated with shrivel symptoms in nectarines was over 2 times that noted for apples. In nectarines percent weight losses required for zero, trace, slight, moderate, severe, and extremely severe shrivel averaged 14, 16, 19, 21, 23, and 25, respectively. Thus over 20 percent weight was lost from nectarines before commercial appearance (moderate shrivel) was affected.

Peaches

One hundred and fifty freshly harvested peaches, in 10 replicate lots of 10 or 20 fruits each, were weighed individually and held on open trays at 75° F and 25 percent relative humidity. Replicates were from Blake, Loring, Red Skin, Red Haven, and unnamed peach cultivars from various harvest dates. Data from the five cultivars were combined for table 1.

At 75° F, percent weight loss in peaches after 1 day ranged from 1 to 8, averaging 4, and after 1 week, percent weight loss ranged from 11 to 27, averaging 20 (table 1). Average weight loss rate for peaches was 2.8 percent per day. The first signs of shrivel were noted around 3 days, and practically all peaches had developed extremely severe shrivel by 7 days. Typical shrivel symptoms for peaches cv. Blake are shown in figure 3. Weight loss associated with shrivel symptoms in peaches was less than (three-fourths as great as) that in nectarines and more than (1½ times) that in apples. In peaches percent weight losses, associated with

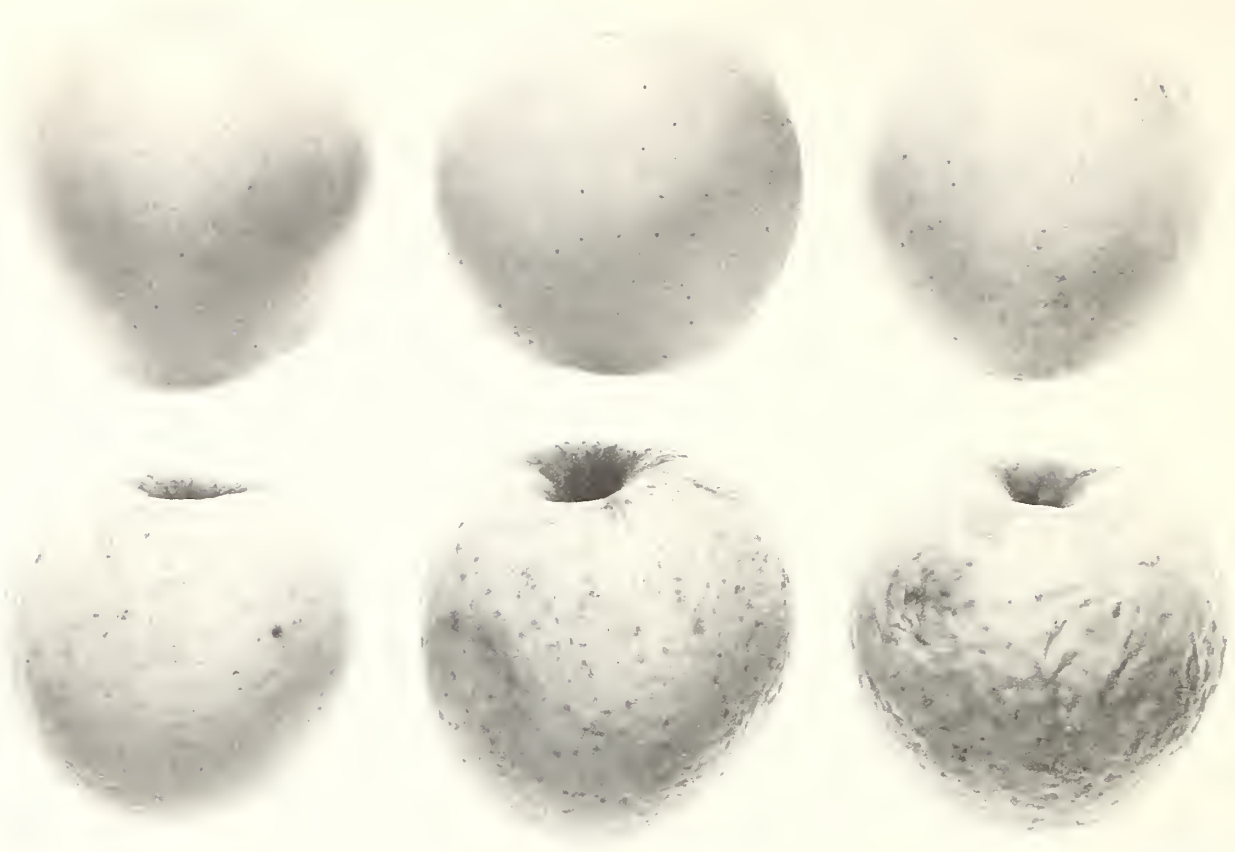

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FIGURE 1.—Shrivel symptoms in apples cv. Golden Delicious: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

zero, trace, slight, moderate, severe, and extremely severe shrivel averaged 9, 11, 14, 16, 18, and 20, respectively. Thus over 16 percent weight was lost from peaches before commercial appearance (moderate shrivel) was affected.

Pears

Three hundred and twenty freshly harvested pears in 8 replicate lots of 40 (20 for each holding room) were taken from three cultivars. Two replicates were from cultivar Magness, three from Moonglow, and three from Giant Seckel. Pears were held at 75° F and 25 percent relative humidity, or at 32° and 95 percent relative humidity.

No significant difference in weight loss attributable to pear cultivar was found in these tests. In one set of tests, however, it appeared that it took most, less, and least weight loss to produce comparable symptoms in Giant Seckel, Moonglow, and Magness pears, respectively. Typical shrivel symptoms for pears cv. Giant Seckel are shown in figure 4. In that set of tests averages of 6, 4, and 3 percent weight losses at 32° F and 11, 9, and 7 percent weight loss at 75° were required to produce moderate shrivel in the three respective cultivars.

After 1 week at 32° F, in pears percent weight loss ranged from 0.6 to 7, averaging 2; while at 75° percent weight loss ranged from 4 to 20, averaging 8 (table 1). At 75° and 25 percent relative humidity, average weight loss rate for pears was 0.7 percent per day. Percent weight losses required to produce slight shrivel symptoms (fig. 4) at 75° ranged from 4 to 15, averaging 7, and at 32° from 2 to 11, averaging 5. Percent weight losses required to produce moderate shrivel symptoms at 75° and 32° averaged 9 and 6, respectively.

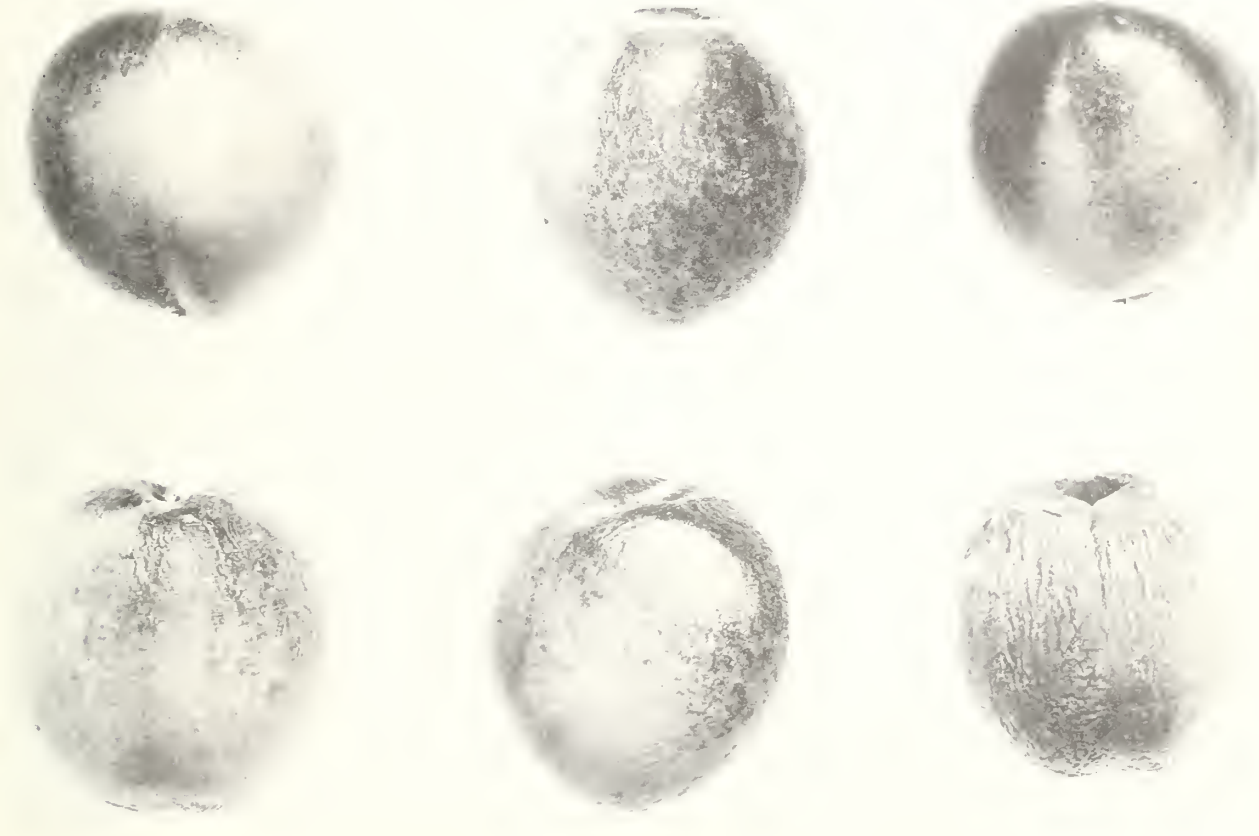
As with apples, the average weight loss required to produce symptoms was higher in pears held at 75° F and 25 percent relative humidity than in pears held at 32° and 95

percent relative humidity with differences in pears ranging from 2 percentage points at trace to 4 percentage points at extremely severe shrivel. Thus, pears at 75° were more resistant to shriveling than pears at 32°. As with apples, pears shriveled faster at 75° than at 32°. At 75° the first signs of shrivel appeared after 2 to 10 days, averaging 5.5 days. Pears showed extremely severe shrivel after 7 to 22, averaging 12 days. At 32° the first sign of shrivel appeared after 3 to 6 weeks, averaging 3.6 weeks. Pears showed extremely severe shrivel after 4 to 12, averaging 8.1 weeks.

Persimmons

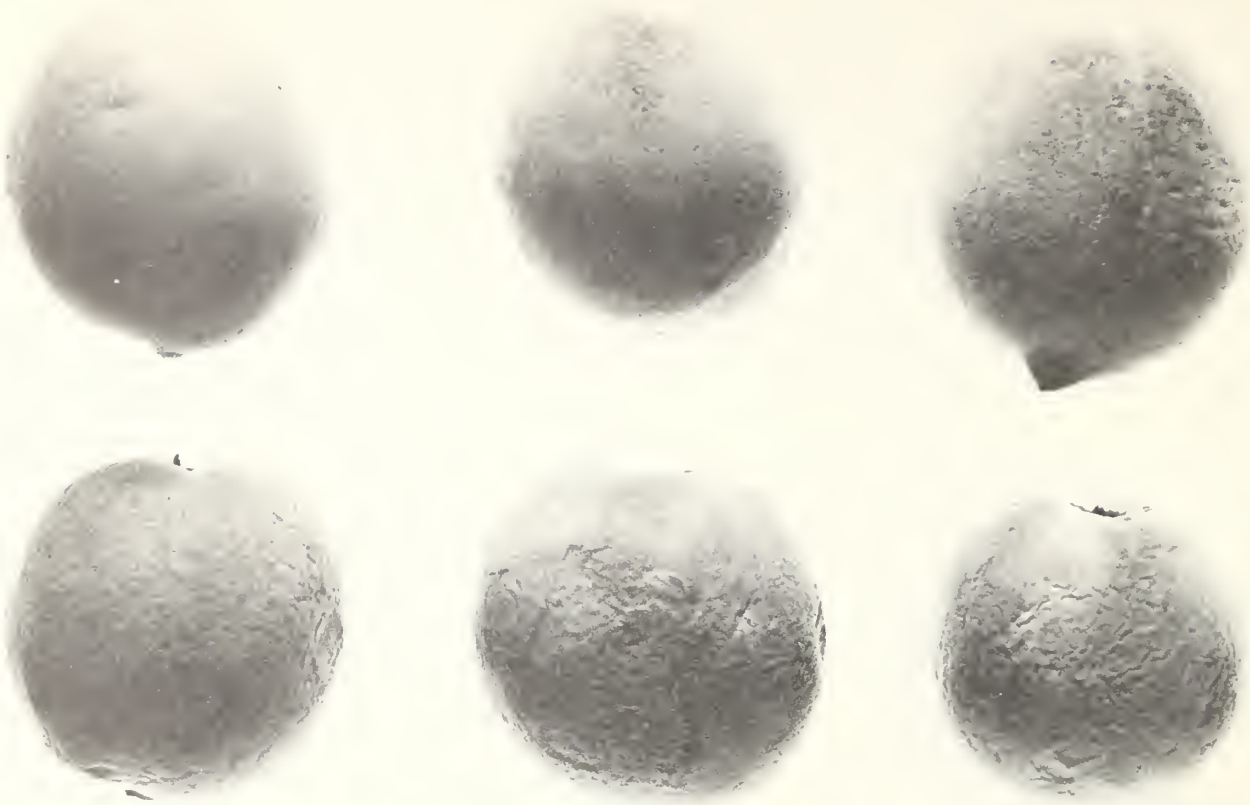
Three replicate test lots, totaling 60 freshly harvested wild American persimmons, and in a small additional test, 10 cultivated Japanese persimmons were held at 75° F and 25 percent relative humidity. Typical shrivel symptoms for American persimmons are shown in figure 5. In American persimmons percent weight losses ranged from 4 to 8, averaging 6, after 3 days; and from 11 to 15, averaging 13, after 7 days (table 1). Thus, they lost weight at a rate of about 1.9 percent per day.

Although data are based on fewer fruit, Japanese persimmons lost weight at less than 1 percent per day, averaging 6 percent lost after 7 days. This difference in weight loss may be due in part to difference in the size of fruit. Japanese persimmons are much larger and have tougher, thicker skin than the Amercian persimmons. The Japanese fruit exhibited a waffled undulated type of shriveling, while the American fruit exhibited finely pleated rough shriveling. Percent weight losses required to produce slight shrivel ranged from 3 to 16, averaging 7, in American persimmons and from 8 to 14, averaging 11, in Japanese persimmons. Percent weight losses required to produce moderate shrivel ranged from 4 to 17, averaging 9, in American persimmons and from 9 to 17, averaging 13, in Japanese persimmons. The first signs of shrivel appeared at 1 to 8 days in American persimmons and at 9 to 13 days in Japanese persimmons, while extremely severe



PN-4912

FIGURE 2.—Shrivel symptoms in nectarines cv. Regal Grand: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.



PN-4913

FIGURE 3.—Shrivel symptoms in peaches cv. Blake: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

shrivel appeared after 3 to 10 days and after 13 to 21 days, respectively.

Vegetables

Beans, Snap

Four hundred freshly harvested snap beans were held at 75° F and 25 percent relative humidity. The beans consisted of 25 each from each of 4 pickings from each of 4 cultivars—Golden Wax (yellow broad), Cherokee Wax (yellow pencil pod), Bountiful (green broad), and Harvester (green pencil pod).

After a half day, percent weight losses ranged from 8 to 18, averaging 12, and after 5 days, ranged from 28 to 83, averaging 51—an overall average rate of about 10.2 percent per day (table 2). Before any symptoms were noted, 12 to 64, averaging 32 percent, were lost from individual beans. Typical shrivel symptoms for snap beans appear in figure 6.

When extremely severe shrivel was noted, percent weight losses ranged from 21 to 83, averaging 52. Deterioration in commercial appearance accompanied moderate shrivel which was noted when snap beans had percent weight losses of 15 to 68, averaging 41. For each of 5 holding days, shrivel symptoms ranged from zero to extremely severe. As time passed, fewer beans were free of shrivel symptoms and more developed progressively severe shrivel. First signs of shrivel were noted in some specimens the first day of holding, and by 5 days most beans had extremely severe shrivel symptoms. In the four snap bean cultivars, commercial appearance and condition were affected, as loss of freshness, when the beans developed moderate shrivel, or turgor loss, symptoms. This deterioration was noted in Golden Wax, Cherokee Wax, Bountiful, and Harvester beans as moderate turgor loss with percent weight loss averages of 40, 48, 49, and 42, respectively, and moderate shrivel with percent weight loss averages of 38, 43, 48, and 36, respectively.

In general it took more weight loss to produce turgor loss or shrivel symptoms in cutivars Cherokee Wax (yellow pencil pod) and Bountiful (green broad) than in Golden Wax (yellow broad) and Harvester (green pencil pod). Cherokee Wax and Bountiful lost more weight per day than Golden Wax. Harvester lost more weight per day than any of the other bean cultivars. This was not a cultivar or variety trial, and pickings of the four cultivars were used as replicates. Thus, no difference in onset of symptoms or rate of weight loss can be attributed to cultivar from these tests. Severity of turgor loss closely approximated severity of shrivel in snap beans. About 37 percent weight loss was required to produce slight turgor loss or shrivel, and 45 and 41 percent weight losses were required to produce moderate turgor loss and shrivel, respectively.

Cabbage, Early

Twenty heads and thirty separated outer (jacket) leaves of freshly harvested early cabbage cv. Copenhagen Market were held at 75° F and 25 percent relative humidity.

After 1 day, percent weight losses ranged from less than 2 to more than 3, averaging 2, for cabbage heads, and 11 to 31, averaging 21, percent for cabbage leaves. Shrivel symptoms for both ranged from zero to trace (table 2). Over the course of the tests cabbage heads lost weight at an average rate of 1.3 percent per day. Typical shrivel symptoms for outer cabbage leaves are shown in figure 7.

After 3 days, shrivel symptoms ranged from zero and trace to severe as percent weight losses ranged from 5 to 8, averaging 7, for cabbage heads and ranged from 24 to 54, averaging 42 for cabbage leaves. Percent weight

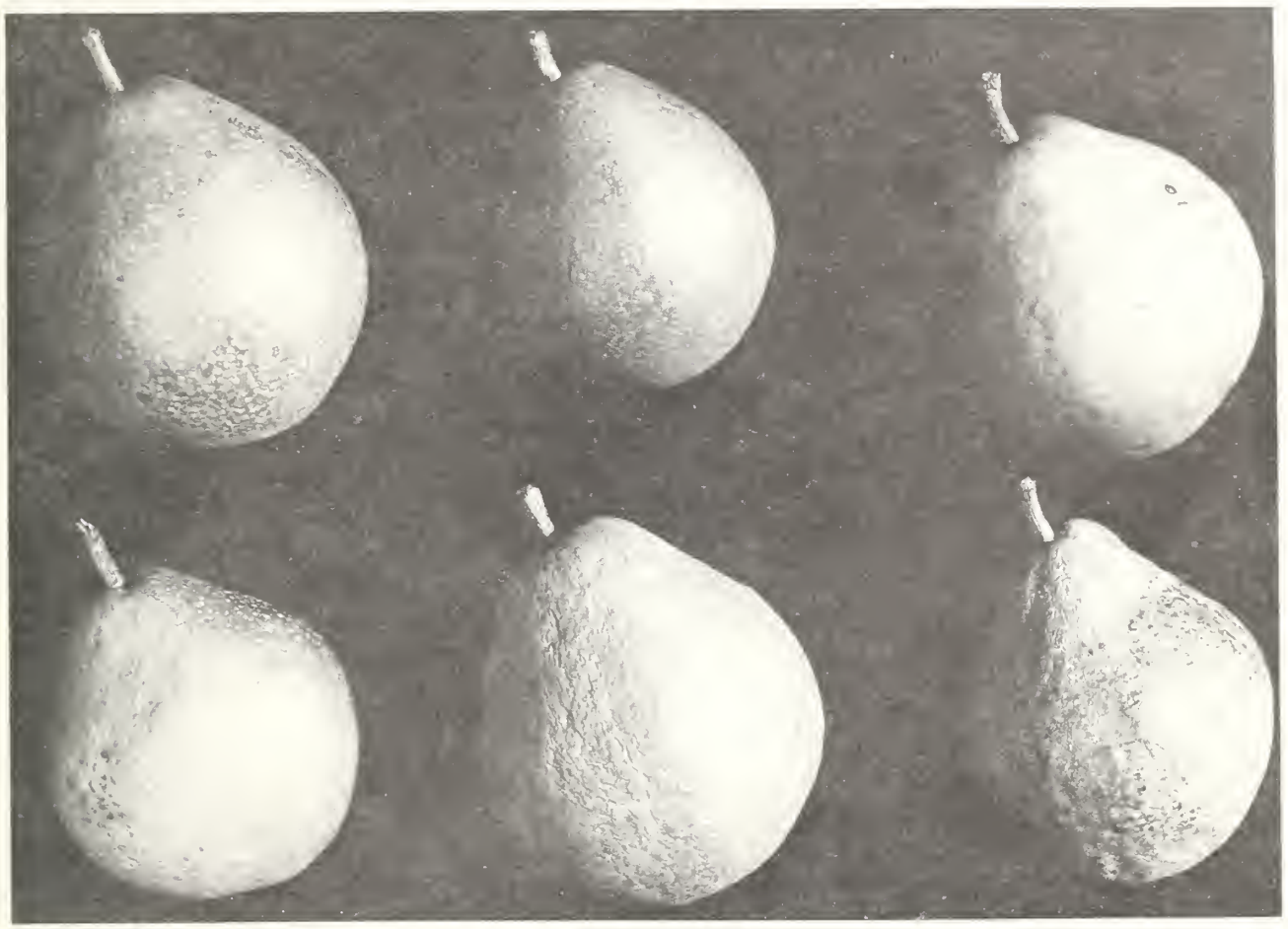


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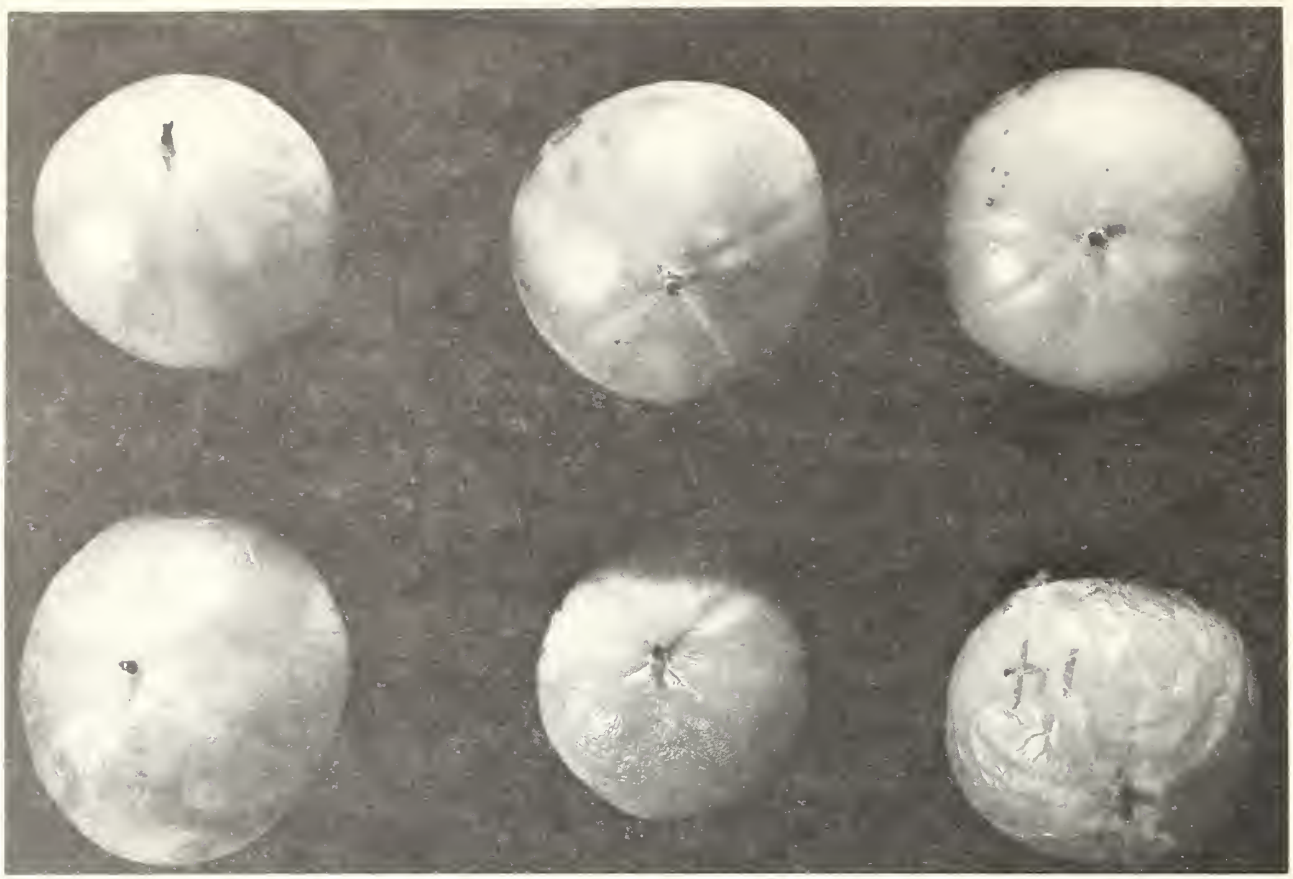
FIGURE 4.—Shrivel symptoms in pears cv. Giant Seckel: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.



PN-4915

FIGURE 5.—Shrivel symptoms in native American persimmons: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

loss by days or at onset of various shrivel symptom ratings was 5 to 10 times as great in leaves as in heads. The first signs of shrivel were noted in both separate leaves and heads after 1 day. Extremely severe shrivel occurred between 7 and 14 days in cabbage leaves and between 10 and 19 days in cabbage heads. Before any shrivel symptoms were noted percent weight losses ranged from 1 to 6, averaging 4, for cabbage heads and 13 to 36, averaging 23, for cabbage leaves. When extremely severe shrivel was noted, percent weight losses of heads ranged from 11 to 25, averaging 18, and leaves ranged from 61 to 85, averaging 78. Before commercial appearance (moderate shrivel) was affected, an average of 50 percent weight was lost from outer leaves and 11 percent from cabbage heads. In cabbage heads most of the weight loss is caused by high evaporation from the outer leaves and less from the inner leaves. Because in weight proportion the head is mostly inner leaves, the average percent weight loss per head is thus much lower than that for separate outer leaves.

Peppers, Sweet

Two hundred freshly harvested sweet peppers cv. California Wonder in groups of 20 from 10 harvests were held at 75° F and 25 percent relative humidity.

After 1 day, percent weight losses ranged from 1 to 5, averaging 3, and after 7 days, ranged from 10 to 25, averaging 15—an overall average rate of about 2.2 percent weight loss per day (table 2). Before any shrivel symptoms were noted in individual peppers, percent weight losses ranged from 1 to 15, averaging 6. Typical shrivel symptoms for peppers are shown in figure 8.

When extremely severe shrivel was noted, percent weight losses ranged from 8 to 27, averaging 15. First signs of shrivel were noted in some specimens by 1 day, and most peppers had extremely severe shrivel symptoms after 7 days. Deterioration in commercial appearance accompanied moderate shrivel symptoms noted when percent weight losses in green peppers ranged from 3 to 22, averaging 12.

Squash, Summer

One hundred freshly harvested summer squash cv. Yellow Crookneck in groups of 20 from 5 harvests were held at 75° F and 25 percent relative humidity. After 1 day, percent weight losses in summer squash ranged from 2 to 10, averaging 6, and after 6 days, losses ranged from 6 to 34, averaging 17—with an overall average after 11 days of about 2.3 percent loss per day (table 2). Before any shrivel symptoms were noted, percent weight losses ranged from 5 to 35, averaging 15, for individual squash. Typical shrivel symptoms for squash are shown in figure 9.

When extremely severe shrivel was noted, percent weight losses ranged from 10 to 58, averaging 31. First signs of shrivel were noted in some specimens after 1 day and most squash had extremely severe shrivel symptoms after 11 days. Deterioration in commercial appearance accompanied moderate shrivel symptoms which were noted when percent weight loss ranged from 9 to 50, averaging 24.

Tomatoes, Firm Ripe

One hundred and forty freshly harvested firm ripe tomatoes cv. Walter in groups of 20 from 7 harvests were held at 75° F and 25 percent relative humidity. After 1 day, percent weight losses in tomatoes ranged from 0 to 1.4, averaging 0.6. After 14 days, the percentages ranged from 3 to 14, averaging 7—an overall average rate of about 0.5 percent weight loss per day (table 2). Before any shrivel symptoms were noted, percent weight loss ranged from 0.3 to 8, averaging 4 for individual tomatoes. Typical shrivel symptoms for tomatoes are shown in figure 10.

When extremely severe shrivel was noted, percent weight losses ranged from 3 to 15, averaging 8. First signs of shrivel were noted after 2 days and by 14 days most tomatoes had extremely severe shrivel symptoms. Deterioration in commercial appearance accompanied moderate shrivel symptoms, which were noted when percent weight losses ranged from 1 to 12, averaging 6.

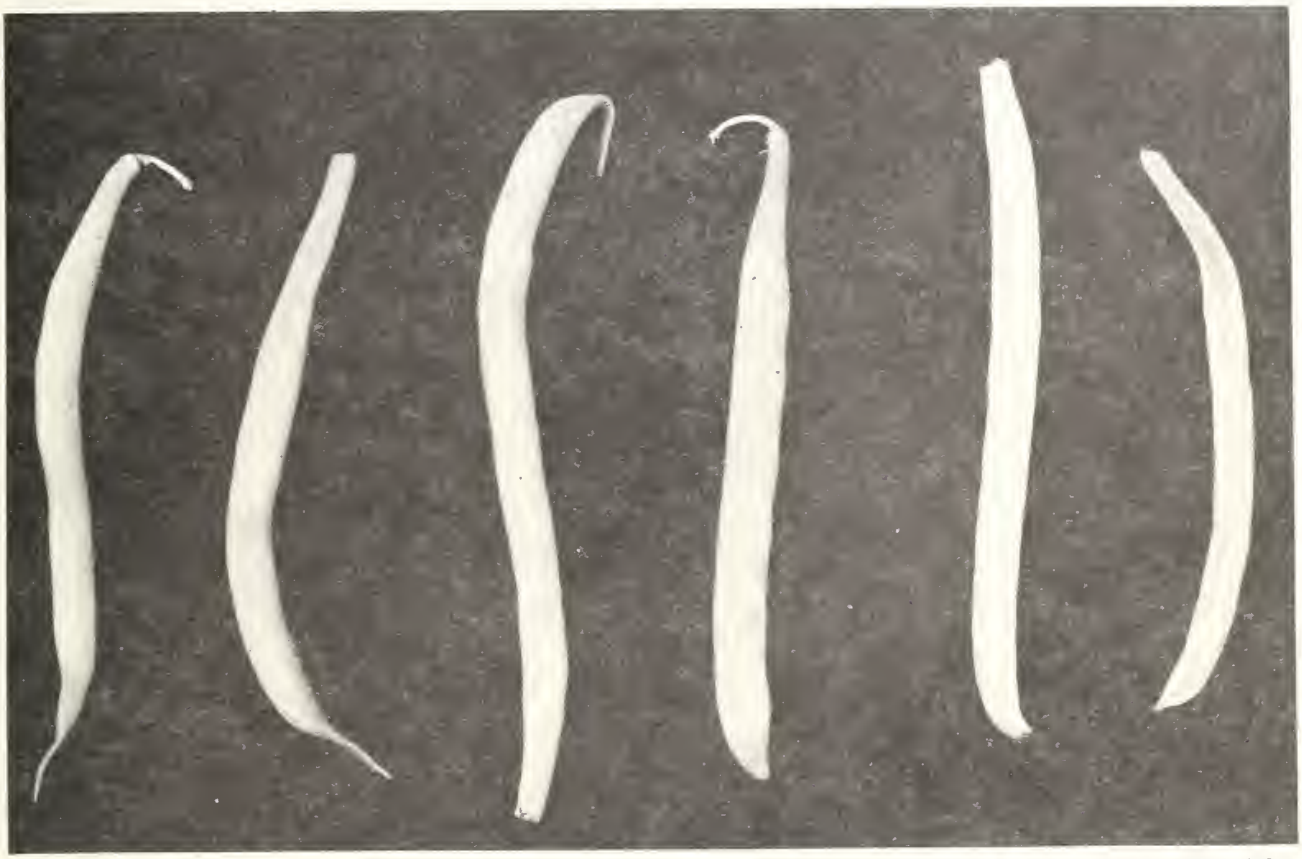


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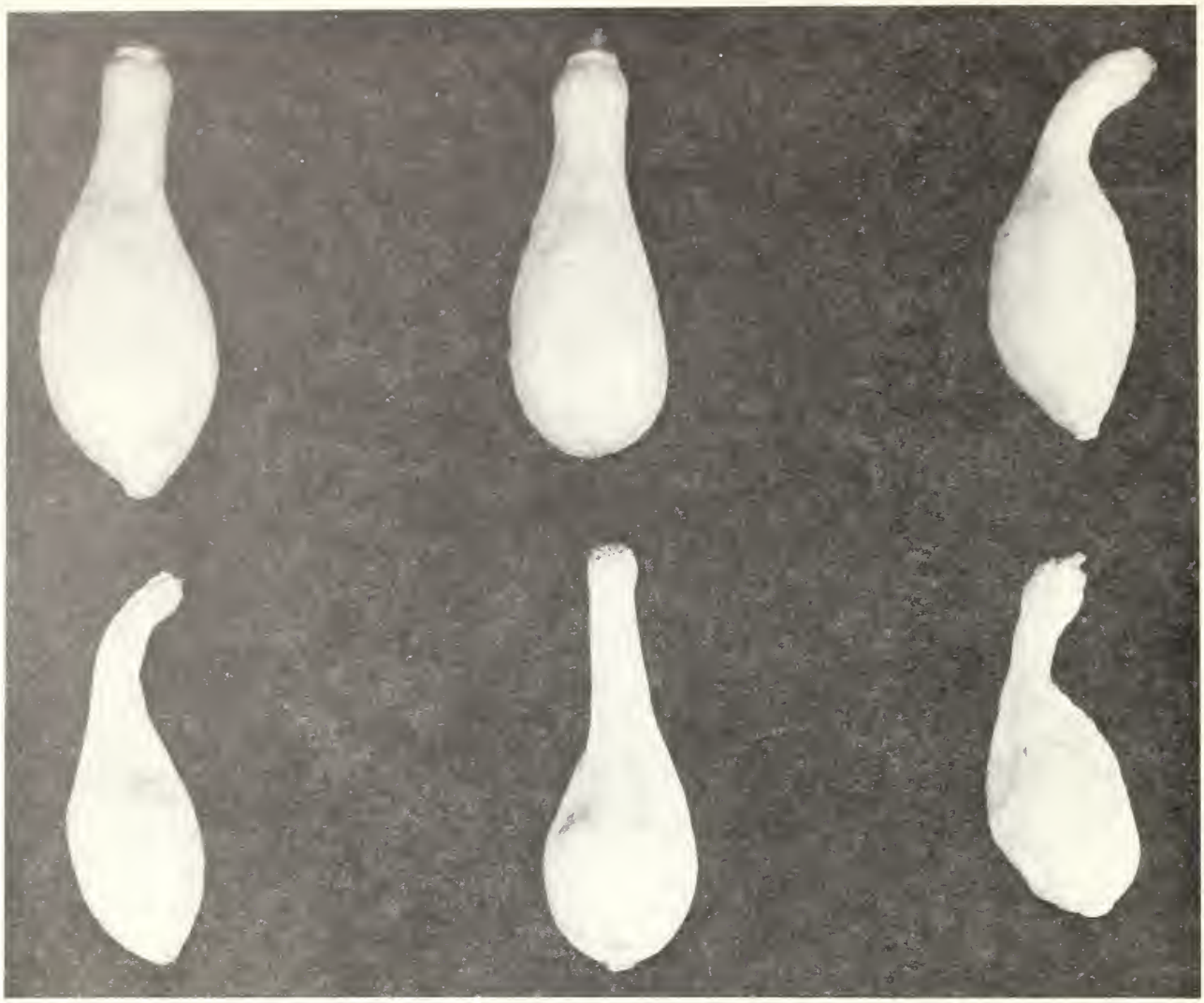
FIGURE 6.—Shrivel symptoms in snap beans (green pencil pod) cv. Harvester: Left to right—zero, trace, slight, moderate, severe, extremely severe.

PN–4917

FIGURE 7.—Shrivel symptoms in outer leaves of cabbage heads cv. Copenhagen Market. Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

PN-4918

FIGURE 8.—Shrivel symptoms in sweet peppers cv. California Wonder: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.



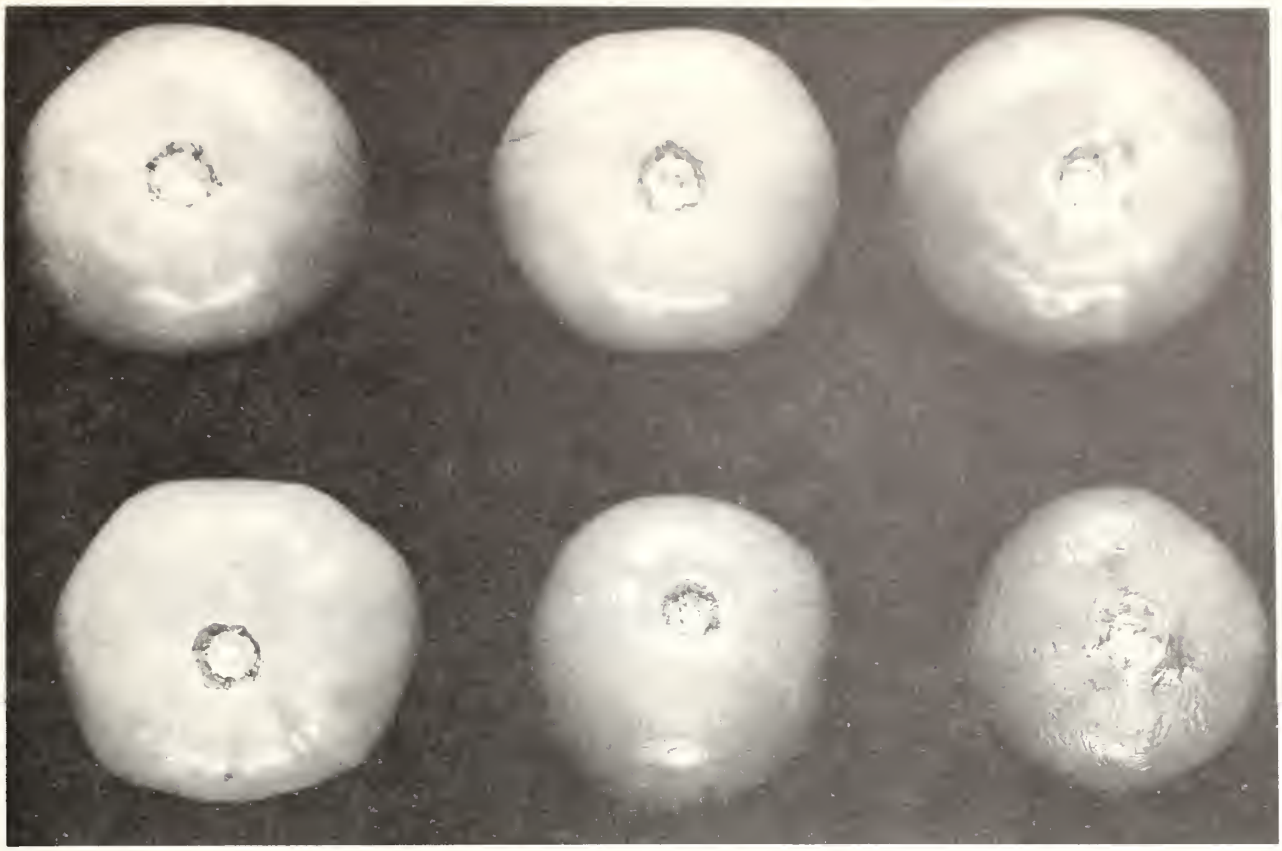
PN-4919

FIGURE 9—Shrivel symptoms in yellow summer squash cv. Yellow Crookneck: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

DISCUSSION

Often-expressed opinion is that in fresh fruits and vegetables shrivel becomes obvious and thus objectionable when weight loss reaches about 5 percent of harvest weight. This opinion is common, despite reports of shrivel associated with weight losses as low as a 3 percent (*2*, *8*, *14*) and as high as 23 percent (*2*, *6*, *7*).

In current tests with fruits and vegetables individually exposed at 75° F and 25 percent relative humidity, weight losses varied widely. When shrivel symptoms in fresh produce was rated moderate or obvious and, therefore, commercially objectionable, weight loss in individual produce specimens ranged from a low of 1 percent in tomatoes to a high of 68 percent in snap beans. Average weight loss associated with moderate shrivel was 6 percent in tomatoes, 41 percent in snap beans, 9 percent in pears, and 21 percent in nectarines (fig. 11). The overall average percent weight loss associated with moderate shrivel in five tested vegetables (detached cabbage leaves excluded) was 19. In five tested fruits, overall average percent weight loss for moderate shrivel was 14. Thus the view associating 5 percent weight loss with objectionable shrivel is not acceptable



PN–4920

FIGURE 10.—Shrivel symptoms in tomatoes cv. Walter: Top row, left to right—zero, trace, slight; bottom row, left to right—moderate, severe, extremely severe.

as a general rule for individual fruits and vegetables. Average weight losses associated with shrivel may be higher than previously supposed. This was a study of weight losses from individual specimens of produce and not of bulk produce packed in containers held under commercial conditions during marketing.

Since much produce is sold by weight, loss of weight through moisture loss is a monetary loss. Before the produce handler becomes aware of moisture loss by the appearance of moderate shrivel, his nectarines may have lost 21 percent weight or his snap beans 41 percent. Shrivel reduces salability causing additional loss. Vitamin loss also occurs when some produce shrivels (*4*, *5*). Thus what has often been considered as a nominal loss of about 5 percent may in fact involve much higher weight and quality losses. When the produce handler realizes the extent and value of possible moisture loss, steps can be taken to prevent or reduce weight loss in fresh fruits and vegetables.

AVERAGE WEIGHT LOSS AT ONSET OF SHRIVEL SYMPTOMS IN FIVE FRUITS AND FIVE VEGETABLES

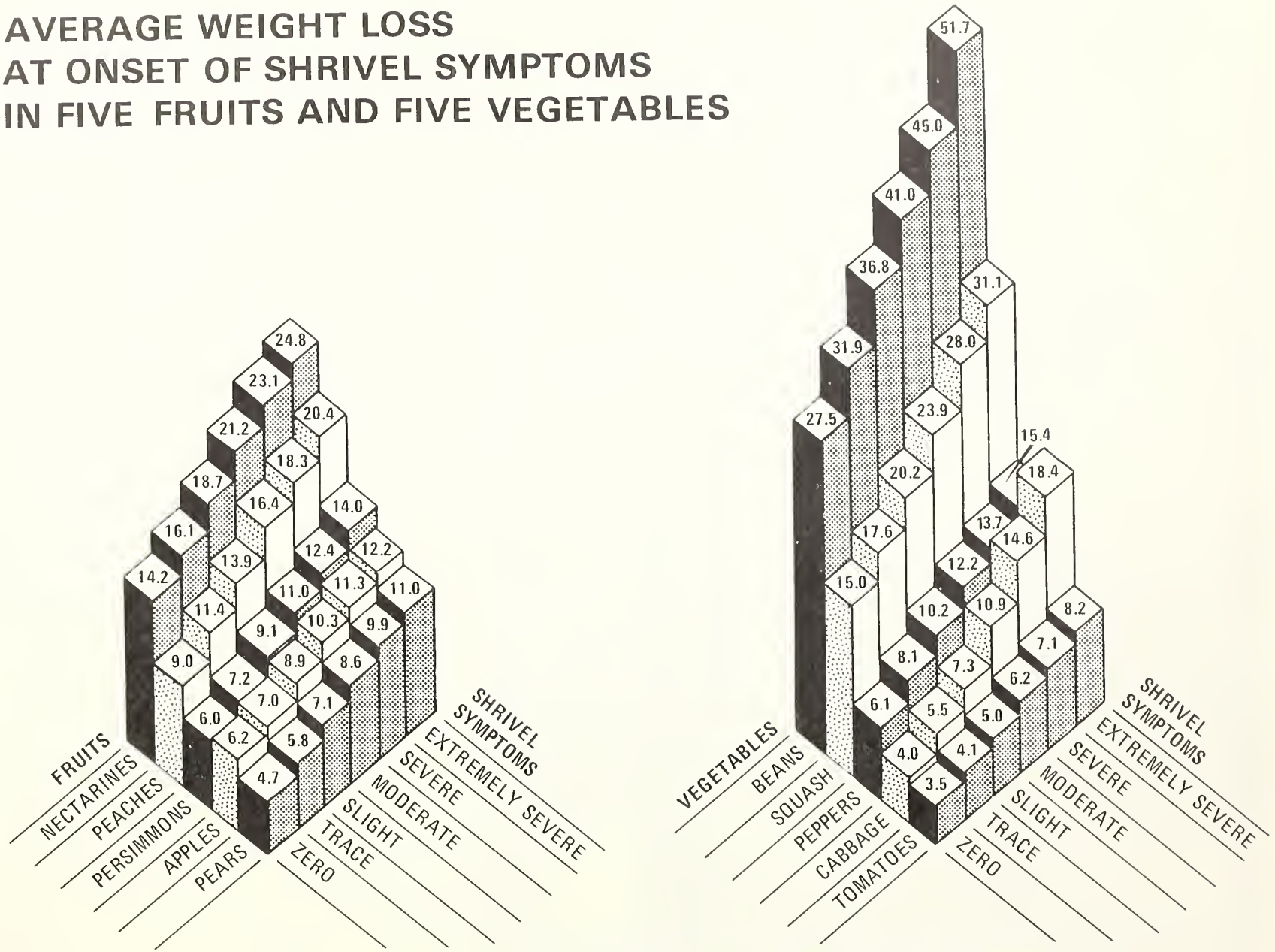


FIGURE 11.—Average percent weight loss at onset of shrivel symptoms in five fruits and five vegetables.

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