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Experiments in *HARVESTING CURING STORING* Yellow Sweet Spanish Onions

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Experiments in

HARVESTING, CURING AND STORING

Yellow Sweet Spanish Onions

by DeLance F. Franklin, D. W. Works and L. G. Williams

The development and use of mechanical onion toppers along with bulk harvesting and storing of the hard globe type onions in the Midwest and East (3) have given growers there an advantage over growers in Idaho and eastern Oregon. Here the more laborious methods of hand-topping and storage in crates and sacks are still used, since the Yellow Sweet Spanish type onions have long been considered too soft for mechanical harvesting and bulk storage.

In Indiana, Wisconsin, Michigan and New York, growers have so perfected their systems of mechanical harvesting and bulk storing operation that they are able to harvest, top and store onions for a fraction of the cost of hand-topping alone to Idaho farmers. At the same time, the Idaho growers' costs have risen markedly with each increase in the cost of labor and crates. Procuring labor at any price becomes more difficult with each succeeding crop year.

Without a satisfactory method for bulk storing and handling of onions, Idaho growers who convert to machine topping will still operate at a disadvantage because of the high costs of hand methods of hauling, warehousing and removing onions from storage.

Present field curing practices (10) vary among growers and also may vary with weather conditions. The onions may be topped immediately after lifting and cured in sacks or crates in the field. Other growers may allow the onions to partially field-cure, following undercutting, before topping. This is followed by additional curing in sacks or crates in the field.

To determine whether costs of harvesting, topping and storing under conventional Idaho methods could be reduced, mechanical harvesting and storing of the Yellow Sweet Spanish type onion were studied.

It was first necessary to determine: What effect present methods of mechanical harvesting would have on the storability of this

type of onion; if this type of onion could be cured in bulk with forced ventilation to avoid adverse effects of wet weather encountered in field curing; and if this type of onion could be held in storage with forced ventilation over relatively long periods of time.

Curing and storing onions in bulk with forced ventilation are considered as two separate operations. Although the requirements for curing differ from those for storing, the same structure and ventilation equipment can be used (2).

Curing is a drying process (8). The object is to remove excess moisture from the outer skin and neck of the onion while minimizing the shrinkage caused by removing moisture from the interior. Good curing conditions consist of circulating warm air of low relative humidity through the onion mass (3). In Idaho, it is normally possible through September and most of October to choose periods of the day for fan operation when the temperature and relative humidity of the air are satisfactory for curing (Figure 13). During periods of adverse conditions, air heated to temperatures of 105-115F (8,10) may be circulated through the onion mass for periods of 16 to 24 hours to hasten the curing process.

A reliable index has not been developed to describe the condition of onions properly cured. Dryness of the neck and condition of the outer skin determined by inspection (2) are criteria upon which experienced growers determine the degree of curing. In general, if the necks feel moist or are pliable, the curing period should be continued (10). Also, a certain amount of conditioning of damaged onions and healing of bruises can be achieved during curing (3).

The object of storing is to maintain the quality of onions for more favorable marketing than that which may occur immediately after harvesting (4). Forced ventilation of quantities of onions stored in bulk is necessary to cool the onions after curing, to remove the heat of respiration and to maintain a uniform temperature throughout the mass during storage.

Franklin (5), working with 5 different combinations of temperature and humidity, determined that Yellow Sweet Spanish strains and 2 derived hybrids had the lowest overall weight losses (rots, sprouts and moisture) in storages of 33F and 50% relative humidity. Bulbs stored at 33F and 70% relative humidity sustained slightly more losses, but survived an extended storage period with better scale retention and better overall appearance.

Although it is not likely that these temperature-humidity conditions can be maintained without refrigeration, it is worthwhile to approach these conditions as closely as possible by coordinating forced ventilation with favorable changes in outside air conditions. This can be achieved most effectively with thermostatic controls in connection with automatic dampers, as hereafter described. Theoretically, this should provide suitable storage conditions through the winter months. If the storage period is to be extended through late spring, refrigerated storage should be considered.

Figure 1. The arrangement and construction of the 8 x 8 x 10 foot bulk bins used for storage during the experiments.

The rate of air flow for forced air storage is determined by the requirements for curing onions rather than for cooling or maintaining storage conditions. The recommended rate of air flow for curing is 1½ cfm (cubic feet of air per minute) per cubic foot of onions (2). The optimum rate will vary depending upon the temperature and relative humidity of the circulating air (3), but conditions of maximum air requirements must be provided.

An air-flow rate of 1½ cfm per cubic foot of onions will remove sufficient moisture from the onions to cure them in two weeks even under relatively poor October drying conditions.

Only half as much air is required for maintaining winter storage conditions as for curing but thermostatic controls will maintain the desired temperature with the higher air flow rate. Two air flow rates, one for curing and one for storage, can be provided by using multiple fan selection. However, a high air flow rate for winter storage will have an advantage during warm periods since maximum cooling can be accomplished while night-time temperatures are low. The higher air-flow rate may also be necessary if the storage period is extended into early spring.

EXPERIMENTAL WORK

Objectives

The experimental work was designed to determine methods which would reduce the cost of harvesting and storing Yellow Sweet Spanish onions. Preliminary investigations (1960-61) indicated that Yellow Sweet Spanish onions could be stored in bulk. The following objectives guided research work:

1. Investigate the effects of bulk storage on Yellow Sweet Spanish type onions.
2. Determine if this type of onion can be cured in storage with forced ventilation, but without the usual field curing practice.
3. Determine conditions favorable for curing and storing.
4. Investigate methods of mechanically handling this type of onion in bulk, in the field at harvest, during placement in storage and removal from storage.
5. Determine the building and ventilation requirements for bulk storage.

Procedure

Various methods of mechanizing handling of the onions were studied. The two systems which involved bulk handling and the use of tote boxes for handling were considered to be the most promising.

Figure 2. Slatted construction of the bin floors.

Figure 3. The Air-Flo onion harvesting machine used for machine-topping of the onions.

1960-61 Experiments

In 1960 two 8 x 8 x 10 foot storage bins were constructed to receive onions for bulk storage (Figure 1). These bins were equipped with slatted floors (Figure 2) to permit forced air ventilation. During this harvest-storage season, the following treatments were used (Table 1):

Treatment No. 011—untopped onions stored in bulk to determine: (1) if the tops would cushion the onions and help prevent bruising; (2) if green tops would present problems in drying; and (3) if the dried tops would present problems on the grading table.

Treatment No. 012—machine-topped onions stored in bulk. A commercial onion harvesting machine (manufactured by Airflo, New York*) was used to top the onions. This machine is shown in use in Figure 3. The purpose of using this treatment was to determine the bulk storage characteristics of the Yellow Sweet Spanish onion and to determine the effect on storability of bruising caused by mechanical harvesting.

Treatment No. 041—machine-topped onions field-cured and stored in crates without forced ventilation but in a ventilated building. Purpose was to evaluate the effect of machine topping and bulk storage.

Treatment No. 051—hand-topped, field-cured onions stored in crates without forced ventilation in the same manner as treatment No. 041 above. This was used as a check to evaluate the various treatments.

In all the treatments, the onions were undercut before harvest-

*Mention of company or trade names of specific equipment is for purpose of identification and does not imply commercial endorsement. This machine was used throughout this work for harvesting and topping the onions referred to as machine-topped, except as otherwise noted.

Table 1. Treatments used in onion storage experiments, Parma Branch Station, 1960-61.

Treatment No.	Type of Storage	Date Undercut	Date Topped	Date Stored	How Cured	How Topped	Curing Period	Curing Air Flow	Storage Air Flow
011	Bulk bin* 8x8x10	9/19	—	9/30	field	untopped	20 days	1.3 cfm/ft³	0.8 cfm/ft³
012	Bulk bin 8x8x10	9/19	9/27	9/30	field	machine	20 days	1.3 cfm/ft³	0.8 cfm/ft³
041	Crated (check)	9/19	9/27	9/30	field	machine	20 days	none	———
051	Crated (check)	9/19	9/27	9/30	field	hand	20 days	none	———

*All bulk storage depth 10 feet.

Table 2. Pack-out and mean percent losses from rots and sprouts in various stored lots of Yellow Sweet Spanish onions, Parma, January 17, 1961.

Treatment No.	Treatment	Weight into Storage	Total U.S. No.1 (Lbs.)	% U.S. No. 1	Total U.S. No. 2 (Lbs.)	% U.S. No. 2	% Rots	% Sprouts
011	Bulk onions untopped	21,010	12,800	60.9	2,070	9.9	6.2	0.4
012	Bulk onions, machine-topped	21,440	14,600	68.1	720	3.4	6.7	0.3
041	Crated onions, machine-topped	3,040	2,150	70.7	90	3.0	3.8	0.0
051	Crated onions, hand-topped	3,165	2,300	72.7	90	2.8	4.2	0.6

Table 3. Mean indices of firmness, scales, roots and color in various lots of stored Yellow Sweet Spanish onions, Parma, January 17, 1961.

Treatment No.	Treatment	Firmness[1]	Scales[2]	Roots[3]	Color[4]
011	Bulk onions, untopped	3.0	3.0	3.0	4.0
012	Bulk onions, machine-topped	3.0	2.2	3.0	4.0
041	Crated onions, machine-topped	3.0	3.0	3.0	4.0
051	Crated onions, hand-topped	3.0	3.6	3.0	4.0

[1]Firmness: 1, soft; 5, very firm; 2-4, intermediate.
[2]Scales: 1, very loose; 5, very tight; 2-4, intermediate.
[3]Roots: 1, pronounced root growth; 5, no root growth; 2-4, intermediate.
[4]Color: 1, pale straw; 5, dark yellow or brown; 2-4, intermediate.

ing to allow the tops to field-dry. Treatments 011 and 012 were only partially field-cured before they were placed in storage. Therefore, they were cured with forced ventilation during the first part of the storage period.

Storage building air was circulated through the onions so onion temperature depended upon the air temperature maintained within the building. Since temperature controls were not provided, the fan was controlled manually. During the curing period, the fan was operated during the day. During the storage period, the fan was operated only long enough to maintain onion temperatures near the inside air temperature of the storage building.

Temperatures were measured at 3-day intervals at thermocouple points within the bin. Air temperatures early in the curing period were above 65F. By October 31, temperature of the bulk onions had decreased to 55F. From December 2 through January 17, storage temperature in the onion piles ranged from 45 to 50F. The rate of air flow for curing was 1.3 cfm per cubic foot of onions. This was reduced to 0.8 cfm during the storage period. Storage records were taken on January 17 and 18, 1961.

1960-61 Results

For total pack-out (Table 2), there was little difference between machine-topped onions stored in bulk and in crates. There was also little or no difference between hand-topped and machine-topped onions stored in crates. Onions with tops attached and stored in bulk packed out a lower percentage of U.S. Number 1 onions than those which were machine-topped and stored in bulk. This difference was attributed largely to the weight of tops and soil which went into the original storage weights. Losses from bruises were greatest in the bottom of each bulk bin.

Evaluation of firmness, rooting and color (Table 3) showed all lots to be equal. But for scale retention, onions which were machine-topped showed more cracked, loose scales and, consequently, more peeled onions than those hand-topped.

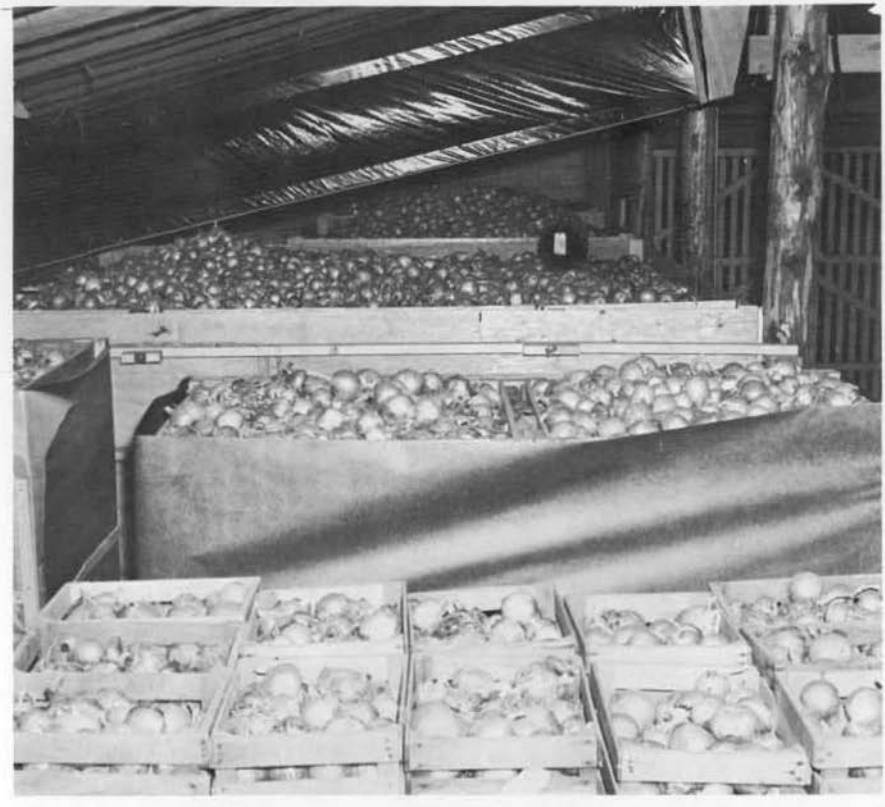

Figure 4. An overhead view showing onions used in the various treatments during the 1961-62 experiments. The overhead air duct which supplied air to the fans (1961-64) can be seen.

Figure 5. A rear-view of the same bins shown in Figure 4, showing the air duct and fan arrangement.

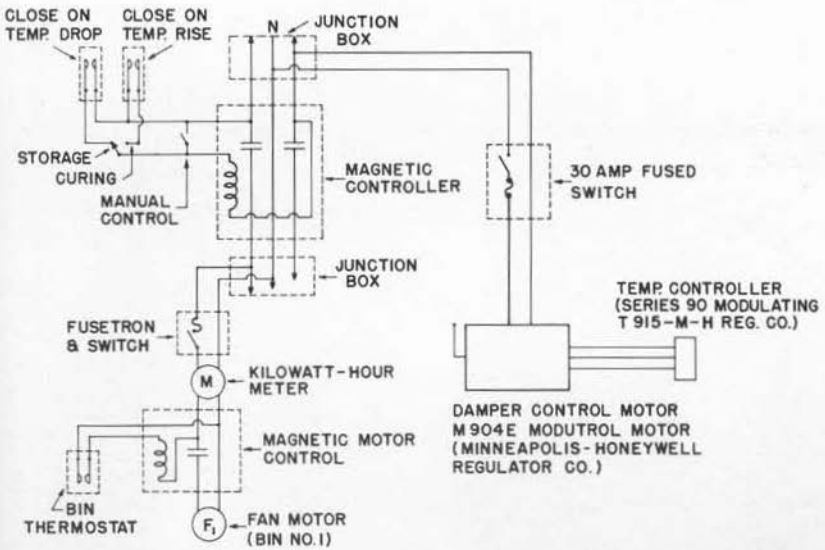

Figure 6. Wiring diagram of the automatic controls used during the experiments.

1961-62 Experiments

In 1961, additional electrical controls were added so desired temperatures could be maintained by using outside air during the curing and storage periods. (Figures 4 and 5). During the curing phase, this was achieved by using a cooling thermostat which opens on temperature drop. This thermostat controlled the main switch so the fans could operate only when the outside air temperature was above the thermostat setting.

A double-pole, double-throw switch was used to disconnect this thermostat and to connect a heating thermostat to the circuit for the storage phase. The fans would not operate when the outside air temperature was higher than the thermostat setting. This setting was lowered from 50 to 35F over a period of one month so that by early December the onion temperature was near the desirable storage temperature of 33F. A schematic diagram of the circuit is shown in Figure 6. In addition, a modulating damper control (Figure 7) was used during the storage period to operate dampers which would allow the proper proportioning of inside and outside air to prevent the cold outside air from being circulated directly through the onions. This was an automatic operation, controlled by a thermostat which was set at 30-33F. To prevent excessive air circulation which would cause desiccation after the onions were cooled for storage, each fan was thermostatically controlled to operate only when the temperature of the onions increased to 38F or higher.

Bulk Storage Bins

In 1961, three treatments of bulk-storage onions with forced ventilation were compared with a check treatment consisting of field-cured onions stored in crates on pallets in the accepted manner

Table 4. Treatments used in onion storage experiments, Parma Branch Station, 1961-62

Treatment No.	Type of Storage	Date Undercut	Date Topped	Date Stored	How Cured	How Topped	Curing Period	Rate of Air Flow
111	Bulk bin 8x8x10	9/14	9/26	9/26	fan	machine	22 days	1.0 cfm/ft^3
112	Bulk bin 8x8x10	9/14	10/2	10/2	field	machine	16 days	0.9 cfm/ft^3
113	Bulk bin 12x12x10	9/14	10/2	10/3	field	machine	15 days	1.3 cfm/ft^3
121	tote boxes 2(4x4x4)	9/22	9/29	9/29	fan	hand	19 days	1.3 cfm/ft^3
122	tote boxes 2(4x4x4)	9/22	10/4	10/4	field	hand	14 days	1.3 cfm/ft^3
123	tote boxes 2(4x4x4)	9/14	10/4	10/4	field	machine	14 days	1.3 cfm/ft^3
131	pallets 2(28 crates)	9/22	9/29	9/29	fan	hand	19 days	1.7 cfm/ft^3
132	pallets 2(28 crates)	9/22	10/4	10/4	field	hand	14 days	1.7 cfm/ft^3
133	pallets 2(28 crates)	9/14	10/4	10/4	field	machine	14 days	1.7 cfm/ft^3
141	crates (check)	9/22	10/5	10/5	field	machine	———	none

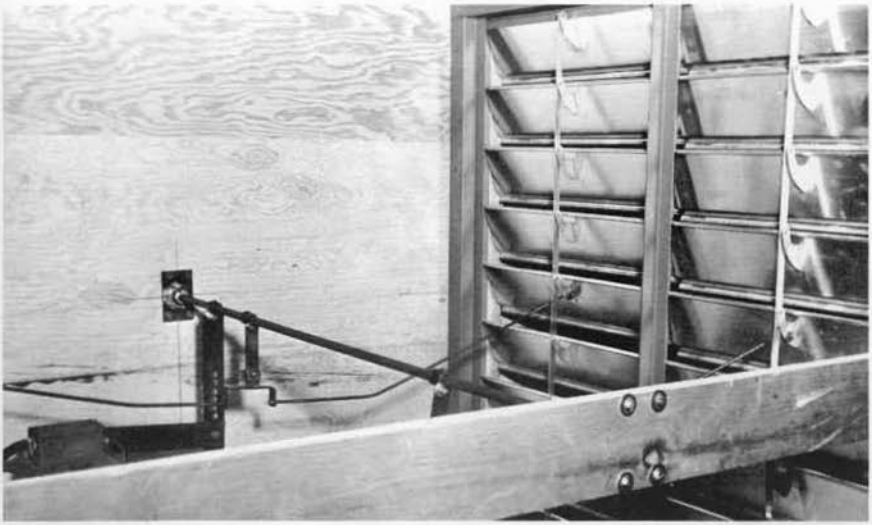

Figure 7. A close-up of the modulating damper system used to mix inside and outside air to obtain ventilating air of the desired temperature.

for storage (Table 4). A 12 x 12 x 10 foot storage bin was constructed to obtain information on pressure bruises that might result from deep bulk storage. The three bulk-storage treatments were:

Treatment No. 111—onions undercut two weeks before mechanical havesting and stored in an 8 x 8 x 10 foot bin. Between undercutting and storing these onions, there was considerable rainfall and it was necessary to wait until field condition were suitable for mechanical harvesting. Although some curing took place in the field, the tops were as green as the harvesting machine would handle. The rate of air flow used for this treatment was 1.0 cfm per cubic foot of onions during the curing and storage periods.

Treatment No. 112—onions topped with an onion harvesting machine and field-cured. The rate of air flow was 0.9 cfm per cubic foot of onions.

Treatment No. 113—onions receiving the same treatment as that of treatment 112, but stored in a 12 x 12 x 10 foot storage bin. Rate of air flow was 1.3 cfm per cubic foot of onions.

Tote Boxes

The second method of handling the onions was in the standard tote boxes commonly used to handle fruit and other products in storage. These boxes are designed so fork lift trucks can be used to move them in and out of storage. Standard 4 x 4 x 4 foot tote boxes were stacked two to a tier and three tiers received air from one fan. The space on the bottom box of each tier, normally used for lifting with a fork-lift truck, was used for the air duct by providing a connecting duct from tier to tier. Each tier was covered with

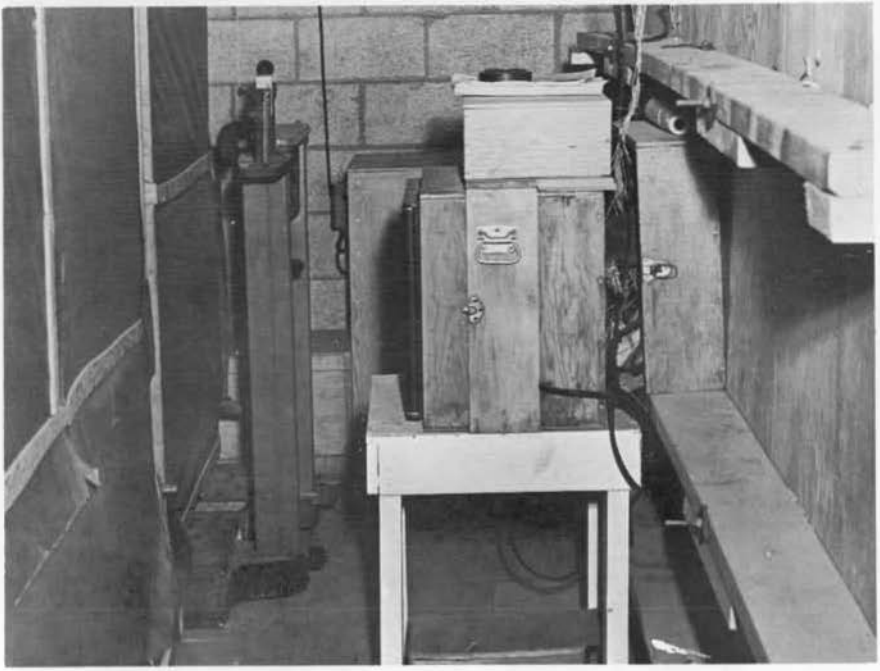

Figure 8. One tier of tote boxes was weighed periodically to determine weight loss. Also, temperature of air and onions was recorded on a recording potentiometer using thermo-couples.

shipping paper to reduce air losses between boxes. Thus, forced ventilation was achieved through the tier and from one tier to another.

The following treatments were used (Table 4):

Treatment No. 121—two tote boxes of onions undercut on September 22 and hand-topped on September 29. They were then placed in storage and cured by using forced ventilation with air supplied at the rate of 1.3 cfm per cubic foot of onions.

To determine onion weight losses, these two tote boxes were placed on scales (Figure 8) so weight could be recorded. The total weight of onions at the beginning of the curing period was 3,971 pounds. Weight loss during the one-month curing period was 191 pounds or 4.8 percent. Additional weight loss during the 2½-month storage period was 46 pounds or 1.2 percent.

Treatment No. 122—two tote boxes of hand-topped onions field-cured 12 days after undercutting. The rate of air flow was 1.3 cfm per cubic foot of onions.

Treatment No. 123—two tote boxes of machine-topped onions field-cured 20 days after undercutting. The rate of air flow was 1.3 cfm per cubic foot of onions.

Pallets

Three other lots of onions were stored in crates stacked on pallets and received treatment similar to those stored in tote boxes. This was done to judge this method of harvesting and storing as an intermediate step between present methods of storage and bulk storage. The treatments were:

Treatment No. 131—1 tier of 2 pallets, each consisting of 28 crates of green, hand-topped onions with no field curing.

Treatment No. 132—2 pallets, 28 crates each, of hand-topped, field-cured onions.

Treatment No. 133—2 pallets, 28 crates each, of machine-topped, field-cured onions. The sides of stacks were sealed with shipping paper to force the air through the onions.

Treatment No. 141—a check treatment of machine-topped, field-cured onions stored in crates without forced ventilation.

1961-62 Results

The onions were removed from storage between January 3 and January 12, 1962. Results of this storage experiment are recorded in Tables 5, 6 and 7 and summarized in the following paragraphs.

Rots. Percentage of rots was greater in the bulk bin storage. This probably resulted from the rougher handling incident to machine topping. However, the percentage of rots in machine-topped onions stored in tote boxes and on pallets was not as great as in those stored in bulk. A high percentage of rots occurred from cuts that did not heal.

Cuts. In all but one case, the percentage of cullage from cuts was significantly higher with machine topping than with hand topping.

Sprouting. More sprouting was observed in hand-topped onions than in machine-topped onions. This may be because hand-topped onion necks are much more closely cropped than the machine-topped onions. This may lead to increased oxygen inside the hand-topped bulbs which may have stimulated sprouting. An adequate internal oxygen supply has long been associated with factors causing top growth from mature onions.

Scale color and scale retention. Hand-topped onions were significantly darker in color and had significantly better scale retention at the end of the storage season than the machine-topped onions. Machine-topped onions, being subjected to harsher treatment such as air blasting, conveying and unloading, lost more of their darker, outer scales than did the hand-topped onions. Scale loss, although significant, was judged not to be excessively injurious to market acceptability of machine-topped onions.

Bulb firmness. Hand-topped bulbs were significantly firmer than machine-topped bulbs in all but one treatment. Machine-topped onions apparently lost a significant degree of firmness with loss of scales and increased handling. However, their market acceptability was not materially impaired.

Table 5. Performance in storage of Yellow Sweet Spanish onions stored in bulk and containers, after different curing and topping schedules, Parma Branch Station, 1961-62.[1]

Treatment No.	Treatment	% U.S. No. 1	% Rots	% Sprouts	% Bald	% Cuts
111	Bulk Bin, 8x8x10 (Machine-topped)	73.3 bc	10.1 a	0.15 d	1.5 cd	0.64 b
112	Bulk Bin, 8x8x10 (Machine-topped)	66.1 d	10.9 a	0.28 cd	2.2 bc	0.50 bc
113	Bulk Bin, 12x12x10 (Machine-topped)	70.1 c	9.2 ab	0.67 cd	3.3 a	0.74 b
121	Tote Box (2) (Hand-topped)	82.4 a	2.7 d	2.40 b	0.8 de	0.00 c
122	Tote Box (2) (Hand-topped)	81.1 a	2.7 d	2.49 b	2.4 b	0.00 c
123	Tote Box (2) (Machine-topped)	72.2 bc	7.7 bc	1.02 cd	1.8 bc	1.63 a
131	Pallet (2) (Hand-topped)	83.1 a	2.1 d	2.88 ab	0.3 e	0.00 c
132	Pallet (2) (Hand-topped)	83.9 a	1.9 d	3.70 a	0.3 e	0.00 c
133	Pallet (2) (Machine-topped)	74.2 b	6.6 c	1.25 c	1.4 cd	1.92 a
141	Crates (Check) (Machine-topped)	73.4 bc	6.0 c	0.74 cd	0.9 de	1.70 a

[1]Letters following numbers denote statistical significance according to Duncan's Multiple Range test. Means followed by letter "a" are significantly different from those means not having "a"; those followed by "b" are significantly different from those not having "b", etc. ($P \leq .05$).

Table 6. Effects on color, scales, firmness, roots and stem plate proliferation of Yellow Sweet Spanish onion bulbs stored in bulk and containers after different curing and topping schedules, Parma Branch Station, 1961-62.[1]

Treatment No.	Treatment	Color[2]	Scales[3]	Firmness[4]	Roots[5]	Proliferation[6]
111	Bulk Bin, 8x8x10 (Machine-topped)	2.9 b	2.9 a	2.8 ab	3.0 a	3.1 a
112	Bulk Bin, 8x8x10 (Machine-topped)	2.6 c	2.4 b	2.2 c	2.0 e	2.0 c
113	Bulk Bin, 12x12x10 (Machine-topped)	2.6 c	2.2 c	2.2 c	2.6 bc	2.3 b
121	Tote Box (2) (Hand-topped)	4.0 a	3.0 a	3.0 a	2.7 b	2.2 bc
122	Tote Box (2) (Hand-topped)	4.0 a	2.8 a	3.0 a	2.7 b	2.2 bc
123	Tote Box (2). (Machine-topped)	3.0 b	2.0 d	2.4 c	2.5 bc	2.2 bc
131	Pallet (2) (Hand-topped)	3.9 a	3.0 a	3.0 a	2.6 bc	2.2 bc
132	Pallet (2) (Hand-topped)	4.0 a	3.0 a	3.0 a	2.5 bc	2.0 c
133	Pallet (2) (Machine-topped)	3.0 b	2.2 c	2.4 c	2.4 cd	2.1 bc
141	Crates (Check) (Machine-topped)	3.0 b	2.0 d	2.7 b	2.2 de	2.0 c

[1]See footnote Table 5.
[2]Color: 1, light straw; 2-4, intermediate; 5, dark yellow or brown.
[3]Scales: 1, very loose; 2-4, intermediate; 5, very tight.
[4]Firmness: 1, soft; 2-4, intermediate; 5, very firm.
[5]Roots: 1, pronounced root growth; 2-4, intermediate; 5, no root growth.
[6]Proliferation: 1, proliferating badly, all specimens showing proliferation; 2-4 intermediate; 5, no proliferation.

Bulb rooting and stem plate proliferation. Significant differences were recorded between treatments but there are no obvious reasons for these differences. In some cases, machine harvest resulted in more damage than hand topping; in others, the reverse was true. Thus, it seems there are determining factors other than the differences in handling.

One possibility is the difference in rate of air movement through the different lots of onions.

Pressure bruises. Pressure bruises were greatest at depths of 8 to 10 feet in the bulk storage bins. There were no pressure bruises at depths up to 6 feet. Some bruising was observed in the 6 to 8 foot level. The most severe pressure bruises were on the very bottom where pressure of the bulbs against the slatted floor materially increased the percentage of pressure bruised specimens.

There were no pressure bruises observed in onions stored in tote boxes nor in crates stored on pallets.

1962-63 Experiments

The ventilation system and controls were the same as those used in the 1961 tests. After the curing period, the thermostats were adjusted to lower the onion temperature with the natural seasonal temperature drop.

Table 7. Temperatures of outside air, of duct air, and in the bulk onion storage, Parma Branch Station, 1961-62.

	OUTSIDE AIR			DUCT AIR			ONION STORAGE (Mean temperature)				
	Mean temp.		Average	Mean temp.		Average	Treatment Number				
Date	Thermograph‡	Thermocouple*	RH	Thermograph	Thermocouple*	RH	111	112	113	121	131
10/ 4/61	52	53	62	51	61	50	53	57	55	56	52
10/11/61	49*	50	—	49	55	59	56	55	61	54	54
10/18/61	41	45	51	45	52	47	57	58	66	54	52
10/25/61	46	43	57	43	44	52	46	46	54	48	47
11/ 1/61	32	42	69	38	42	59	46	44	51	45	43
11/ 8/61	31	32	70	31	31	58	37	36	45	38	37

*Mean temperature computed: $\frac{\max + \min}{2} = \text{mean}$

‡Official Records of Parma Experiment Station

Bulk Storage Bins

Again, three bulk storage samples were cured and stored to obtain additional information on the storability of the Yellow Sweet Spanish onion (Table 8). Treatments were:

Treatment No. 211—onions with green tops stored September 11 in an 8 x 8 x 10 foot bin. The rate of air flow was 1.6 cfm per cubic foot of onions.

Treatment No. 212—onions topped with an onion harvester, field-cured and stored in an 8 x 8 x 10 foot bin. There were not enough of these onions to fill the bin so the remaining space was filled with other stock to obtain information on pressure bruising. Results from this bin were not analyzed.

Treatment No. 213—onions harvested in the same manner as treatment 212, but stored in a 12 x 12 x 10 foot bin. The air flow rate was 1.4 cfm per cubic foot of onions.

Tote Boxes

Specially built boxes with solid sides, 4 x 4 x 2½ feet in size, were used. Each box held approximately 1,500 pounds of onions. The fork-lift space on the bottom box was again used for the air duct by providing connecting ducts from one tier to the next. This space on the other boxes was sealed by tacking on a piece of ¼-inch plywood after the box was in storage position. Cracks between boxes stacked in tiers were sealed with duct tape. Thus, forced ventilation was achieved through the tier and from one tier to another. The boxes were stacked 3 to a tier in these experiments (Figure 9).

Green, untopped onions; green, hand-topped; and green onions topped with a flail chopper* before undercutting were cured in tote boxes and compared with machine-topped, field-cured onions stored in tote boxes. These treatments were also compared with machine-topped, field-cured onions and with hand-topped, field-cured onions stored in crates without forced ventilation (Table 8). Treatments were:

Treatment No. 221-2—6 tote boxes of green untopped onions stacked in 2 tiers and cured in storage with forced ventilation, using an air flow rate of 1.4 cfm per cubic foot of onions.

Treatment No. 224—3 tote boxes of green, hand-topped onions receiving forced ventilation at an air flow rate of 0.8 cfm per cubic foot of onions.

Treatment No. 225—3 tote boxes of green onions topped with a flail chopper before undercutting. This sample was ventilated the same as treatment 224.

Treatment No. 226—3 tote boxes of machine-topped, field-cured onions receiving the same ventilation as treatments 224 and 225.

Treatment No. 241—machine-topped, field-cured onions stored in crates on pallets without forced ventilation.

*Chopper manufactured by International Harvester Company.

Table 8. Treatments used in onion storage experiments, Parma Branch Station, 1962-63

Treatment No.	Type of Storage	Date Undercut	Date Topped	Date Stored	How Cured	How Topped	Curing Period	Rate of Air Flow
211	Bulk Bin 8x8x10	9/10	——	9/11	fan	untopped	40 days	1.6 cfm/ft³
212	Bulk Bin 8x8x10	9/10	10/17	10/18	field	machine	3 days	1.6 cfm/ft³
213	Bulk Bin 12x12x10	9/10	10/18	10/19	field	machine	2 days	1.4 cfm/ft³
221-2	Tote boxes 6(4x4x2½)	9/10	——	9/10	bin	untopped	41 days	1.4 cfm/ft³
224	tote boxes 3(4x4x2½)	9/12	9/12	9/12	bin	hand	39 days	0.8 cfm/ft³
225	tote boxes 3(4x4x2½)	9/12	9/12	9/12	bin	flail chop	39 days	0.8 cfm/ft³
226	tote boxes 3(4x4x2½)	9/12	10/11	10/11	field	machine	10 days	0.8 cfm/ft³
241	crates (check)	9/12	10/11	10/12	field	machine	——	none
251	crates (check)	9/12	10/8	10/12	field	hand	——	none

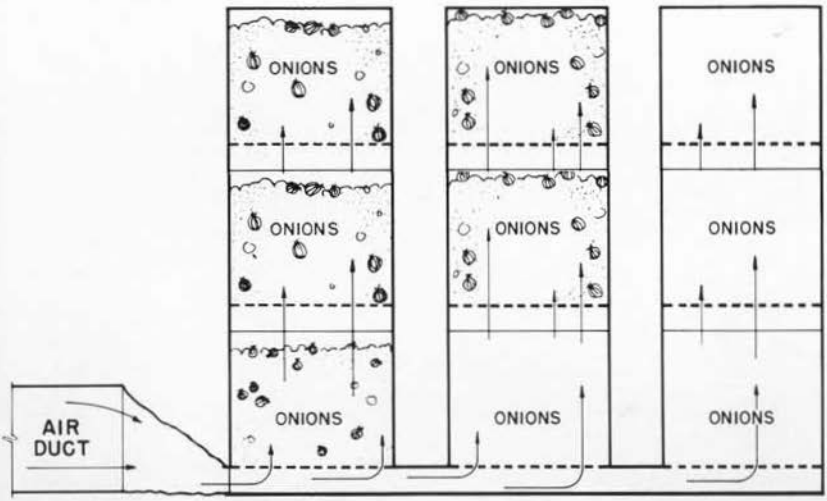

Figure 9. Onions stored in tote boxes were stacked 3 to a tier and 3 tiers per fan. Air was conveyed from tier to tier by small air ducts on the bottom box.

Treatment No. 251—hand-topped, field-cured onions stored in crates on pallets without forced ventilation to determine the effect of machine-topping on storage.

In Table 9, the mean temperature for the 24-hour period is shown for every fifth day during the curing and storage period of all treatments.

1962-63 Results

The onions were removed from storage from January 18 through 25. Results of this storage, as indicated by onion condition and comparison of the various tests, are recorded in Tables 10 and 11 and summarized in the following paragraphs.

Rots. Percentage of rots in bulk bin treatment 213, containing machine-topped onions, was statistically no greater this year than that of onions hand-topped and stored in crates. Thus, machine topping **per se** did not significantly increase rotting despite the fact that hand-topped onions stored in crates, treatment 251, showed significantly less rots than machine-topped onions stored in crates, treatment 241. In this case, the hand-topped onions were topped directly from the field into crates and stored. The machine-topped onions were topped into a bulk truck, unloaded into crates and then stored. It seems probable that this increased handling and incidental bruising were responsible for the increase in rots shown here.

All onions stored with green tops attached showed a highly significant increase in rots compared to onions topped either by hand or by machine.

Cuts. The incidence of cuts is significantly less in the hand-topped and untopped onions, but the differences do not appear large

Table 9. Temperatures recorded during curing and storage of onions, Parma Branch Station, 1962-63

Date	Air Temp.			Duct RH	Treatment No.						
	Outside	Inside	Duct		211	212	213	221-3	224	225	226
9/15	59.2	64.0	64.2	——	—	59.5	—	60.0	61	60	71
9/20	61.9	64.2	63.9	64.0	—	61	—	58	58.5	59.5	71
9/25	57.3	61.7	61.5	57.9	—	60	—	55.5	60	60	70
9/30	45.2	52.7	57.7	60.7	—	58	—	56	57	57.5	56
10/ 5	46.1	53.1	51.3	54.6	—	52.5	—	51.5	53	54	56
10/10	46.9	50.8	—	74.0	—	53.5	—	54	53	53.5	50.5
10/15	43.6	49.6	47.3	65.2	—	49	—	48.5	49	49	56
10/20	45.1	50.0	46.7	69.9	47	49	52.5	49	49	49	55
10/25	40.7	47.2	71.4	71.4	45.5	47	49.5	47.5	49.5	50.0	57.5
10/30	41.9	45.8	44.7	75.1	46	47.0	49.0	47.0	46.5	47.0	53.5
11/ 4	40.5	46.0	43.6	74.2	43	45.0	46.0	45.0	45.0	45.5	53.0
11/ 9	37.5	40.8	39.7		39.5	41.0	41.5	42.0	41.5	42.0	49.5
11/14	38.7	43.8	41.3	71.5	42.0	42.5	44.0	42.5	43.5	44.0	51.0
11/19	35.2	39.8	38.4	72.7	39.0	40.0	40.5	40.5	40.0	40.0	46.5
11/24	25.5	36.3	35.8	69.8	36.0	37.5	38.0	38.0	41.0	40.5	46.0
11/29	26.8	38.1	35.3	69.1	37.0	37.0	38.0	38.0	40.0	40.0	44.5
12/ 4	33.6	39.3	37.6		38.0	39.0	40.0	39.5	40.0	40.0	46.0
12/ 9	33.0	38.2	36.0		37.5	38.0	38.0	38.5	39.0	38.0	
12/14	32.8	38.4	36.8	72.3	37.5	38.5	38.5	38.5	38.5	38.5	46.0
12/19	35.3	41.6	33.3		40.0	40.5	41.0	40.0	41.0	41.5	49.0
12/24	30.5	36.5	37		34.5	35.5	36	36	37	37	42.5
12/29	16	32.5	33		33.5	36.5	36	35.5	35	35.5	42
1/ 3	38.5	38.5	39.5		38	38.5	38	35.5	35	35.5	41
1/ 8	30	36.5	35.5		36	37	38	37	36	36	42.5
1/13	17	32.5	34		34	36.5	38	35	34	34.5	40
1/18	24	37	40		37.5	39.5	39.5	33.5	33	34	40.5
1/23	34	40	44.5		34.5	36.5	47.5	40	38.5	39	45.5

enough to rule out machine topping. Modification of the topping machine by reducing belt speeds, eliminating corners from right-angle turns on conveyors and reducing the distance of fall from the conveyor to the truck virtually eliminate mechanical sources of bulb injury.

Sprouting. Again sprouting was significantly greater in hand-topped than in machine-topped onions.

Scale color and scale retention. Table 11 shows that generally the machine-topped onions were as dark in color as hand-topped onions. This is contrary to results from the previous year, and it suggests that modifications in the Airflo conveyor and fan, plus better handling in loading and unloading the bulk piles, were effective in reducing scale loss. Scale color was darker in some machine-topped onions than in some hand-topped onions. This may be due to better aeration afforded these particular machine-topped onions. Untopped onions (treatment 211) in the bulk bin showed less color than untopped onions treated and stored in tote bins. For this there is no obvious explanation.

Although scale retention did not precisely follow the pattern of the previous year's results, machine-topped onions generally were less retentive of scales than were the hand-topped bulbs.

Firmness. Once again, hand-topped bulbs were firmer at the end of the storage period than machine-topped bulbs. Little difference was observed in the firmness of untopped bulbs compared to machine-topped bulbs.

Table 10. Performance in storage of Yellow Sweet Spanish onions stored in bulk and containers, after different curing and topping schedules, Parma Branch Station, 1962-63. [1]

Treatment No.	Treatment	% U.S. No. 1	% Rots	% Sprouts	% Cuts
211	Bulk Bin, 8x8x10 (Untopped)	67.8 d	21.9 a	0.00 c	.00 b
213	Bulk Bin, 12x12x10 (Machine-topped)	82.7 ab	2.8 de	0.12 c	.53 a
221	Tote Bin (3) (Untopped)	73.1 cd	21.2 a	0.00 c	.00 b
222	Tote Bin (3) (Untopped)	77.2 bc	14.5 b	0.28 b	.00 b
224	Tote Bin (3) (Hand-topped)	81.4 ab	5.4 cd	0.73 ab	.00 b
225	Tote Bin (3) (Flail chopper)	75.6 bc	8.9 c	0.55 bc	.00 b
226	Tote Bin (3) (Machine-topped)	87.8 a	.8 e	0.52 bc	.00 b
241	Crates, check (Machine-topped)	76.3 bc	8.8 c	1.27 a	.57 a
251	Crates, check (Hand-topped)	86.6 a	1.7 de	0.83 ab	.13 b

[1]Letters following numbers denote statistical significance according to Duncan's Multiple Range test. Means followed by letter "a" are significantly different from those means not having "a"; those followed by "b" are significantly different from those not having "b", etc. ($P \leq .05$)

Bulb rooting. Although the differences were not always significant, the untopped bulbs showed less rooting than machine-topped and hand-topped bulbs. The most rooting was observed where onions were machine-topped and stored in crates.

Stem plate proliferation. When stored in crates, machine-topped onions showed significantly more stem plate proliferation than hand-topped onions. Otherwise there was no significant difference except for untopped onions stored in bulk (treatment 211). Here there was less proliferation than in any of the other treatments.

Pressure bruises. Table 12 data show the effects of deep storage on Yellow Sweet Spanish onions as reflected by pressure bruising from storage in a 12 x 12 x 10 foot bin (treatment 213). Although this does not exactly represent conditions of bulk storage, the 12 x 12 x 10 foot bin was as large a storage as was practical under these conditions.

There were no pressure bruises up to storage depths of 6 feet. There were some pressure bruising losses in the 2-foot level from 6 to 8 feet of storage depth, so some pressure bruises can be expected in bulk storage at this depth level. At depths greater than this, considerable bruising may result.

The slatted floor appeared to increase pressure bruising in

Table 11. Effects on color, scales, firmness, roots, and stem plate proliferation of Yellow Sweet Spanish onion bulbs stored in bulk and containers, after different curing and topping schedules, Parma Branch Station, 1962-63.[1]

Treatment No.	Treatment	Color[2]	Scales[3]	Firmness[4]	Roots[5]	Proliferation[6]
211	Bulk Bin, 8x8x10 (Untopped)	3.3 c	3.2 ab	2.4 d	3.1 b	3.3 a
213	Bulk Bin, 12x12x10 (Machine-topped)	3.9 a	2.8 c	3.0 bc	2.2 d	2.8 b
221	Tote Bin (3) (Untopped)	3.7 ab	3.1 a-c	2.9 c	3.5 a	2.9 b
222	Tote Bin (3) (Untopped)	3.7 ab	3.2 ab	2.9 c	3.2 ab	3.0 b
224	Tote Bin (3) (Hand-topped)	3.4 bc	3.1 a-c	3.3 a	2.9 bc	2.9 b
225	Tote Bin (3) (Flail chopper)	3.5 bc	3.3 ab	3.0 bc	3.0 bc	3.0 b
226	Tote Bin (3) (Machine-topped)	3.7 ab	2.9 bc	2.9 c	2.9 bc	3.0 b
241	Crates, check (Machine-topped)	3.9 a	2.9 bc	2.9 c	1.7 e	2.1 c
251	Crates, check (Hand-Topped)	4.0 a	3.4 a	3.2 ab	2.7 c	2.9 b

[1]See footnote Table 10.
[2]Color: 1, light straw; 2-4, intermediate; 5, dark yellow or brown.
[3]Scales: 1, very loose; 2-4, intermediate; 5, very tight.
[4]Firmness: 1, soft; 2-4, intermediate; 5, very firm.
[5]Roots: 1, pronounced root growth; 2-4, intermediate; 5, no root growth.
[6]Proliferation: 1, proliferating badly, all specimens showing proliferation; 2-4, intermediate; 5, no proliferation.

Table 12. Percentage of onions not graded U.S. No. 1 because of pressure bruising in bulk storage, Parma Branch Station, 1962-63.

Treatment No.	Sample Depth[1]	Sample Location	Weight Out, Lbs.	Pressure Bruises (lbs.)	% Loss
213 (12'x12'x10' bin)	6-8 ft.	Center of bin	62.8	0.5	0.8
Same	8-10 ft.	Center of bin	65.7	6.4	9.7

[1]Since there were no pressure bruises in the upper layers, data for depths less than 6 feet are not presented.

onions directly in contact with the floor. Therefore, some bruising may result at this point even when onions are stored at 6 to 8 foot depths.

Because of these two factors, storage depths in large areas will probably be limited to 6 to 8 feet. However, some sacrifice of quality may be economically justified through reduced labor costs in harvesting and handling onions in bulk.

1963-64 Experiments

Onion harvest in 1963 was scheduled earlier than in previous years to obtain additional information on curing the Yellow Sweet Spanish Onion. The ventilation system and controls were the same as those used in 1961 tests. Following the curing period, the thermostats were adjusted to lower the onion temperature with the natural seasonal temperature drop.

Bulk Storage Bins

Only two bulk storage samples were cured and stored, (Table 13). Treatments were:

Treatment No. 311—untopped onions taken directly from the field September 12 without any curing and stored in an 8 x 8 x 10 foot bin. The curing period was 30 days, and the rate of air flow was 1.7 cfm per cubic foot of onions for both curing and storage periods. An air leak in duct work leading to this bin greatly reduced the air flow through the onions. It became necessary to remove part of the onions to prevent overheating and loss of the total bin. Data were therefore not available for analysis.

Treatment No. 312—onions topped with an onion harvester 10 days after undercutting, field-cured part of 1 day and stored in an 8 x 8 x 10 foot bin September 27. The rate of air flow was 1.4 cfm per cubic foot of onions.

Tote Boxes

Several treatments were used to obtain information on harvesting procedures and machines for topping and loading and to determine the effects that these methods might have on storage. The various treatments, shown in Table 13, were:

Table 13. Treatments used in onion storage experiments, Parma Branch Station, 1963-64

Treatment No.	Type of Storage	Date Undercut	Date Topped	Date Stored	How Cured	How Topped	Curing Period	Rate of Air Flow
311	Bulk Bin 8x8x10	9/12	——	9/12	fan	untopped	30 days	1.7 cfm/ft³
312	Bulk Bin 8x8x10	9/16	9/26	9/27	field	machine[1]	14 days	1.4 cfm/ft³
321	tote boxes 3(4x4x2½)	9/12	9/12	9/13	fan	hand[2]	30 days	1.5 cfm/ft³
322	tote boxes 3(4x4x2½)	9/12	9/12	9/13	fan	hand[3]	30 days	1.5 cfm/ft³
323	tote boxes 3(4x4x2½)	9/12	9/12	9/13	fan	flail chop[2]	30 days	1.5 cfm/ft³
324	tote boxes 3(4x4x2½)	9/16	9/26	9/26	field[5]	machine[4]	14 days	1.5 cfm/ft³
325	tote boxes 3(4x4x2½)	9/16	9/26	9/26	field[5]	machine[4]	14 days	1.5 cfm/ft³
326	tote boxes 3(4x4x2½)	9/16	9/26	9/26	field[5]	hand[2]	14 days	1.5 cfm/ft³
341	crates (check)	9/16	9/26	9/26	field	machine[1]	——	none
351	crates (check)	9/16	9/21	9/26	field	hand	——	none

[1]Loaded into truck by topping machine
[2]Picked up by hand, tote box loaded in the field
[3]Tote boxes loaded with a potato harvester
[4]Picked up by topping machine, tote box loaded in the field
[5]Partially field cured

Treatment No. 321—green, hand-topped onions, picked up and loaded by hand into tote boxes in the field and cured in storage for 30 days. The rate of air flow for both the curing and storage periods was 1.5 cfm per cubic foot of onions.

Treatment No. 322—green, hand-topped onions, picked up and loaded into tote boxes with a potato harvester (Figure 10) and cured in the same manner as treatment 321.

Treatment No. 323—green onions topped before undercutting with a flail chopper designed and built by the Agricultural Engineering Department, University of Idaho (Figure 11). The onions were picked up by hand, loaded in tote boxes in the field and cured in storage the same as treatment 321.

Treatment No. 324-5—onions undercut and field-cured for 10 days, machine-topped, loaded directly into tote boxes from the machine and cured in storage for 14 days. The rate of air flow for both curing and storage was 1.5 cfm per cubic foot of onions.

Treatment No. 326—onions undercut and field-cured for 10 days, hand-topped, picked up by hand and loaded into tote boxes and cured in storage in the same manner as treatment 324-5.

Treatment No. 341—machine-topped, field-cured onions stored in crates without forced ventilation for use as a check.

Treatment No. 351—hand-topped, field-cured onions stored in crates without forced ventilation to determine the effects of machine topping on stored onions.

The mean temperature recorded for the 24-hour period is shown in Table 14 for every fifth day during the curing and storage periods.

Figure 10. A potato harvester used in conjunction with the flail topper (1963-64) to pick up the topped onions.

Table 14. Temperatures recorded during curing and storage of the onions, Parma Branch Station, 1963-64

Date	Air Temp.			Treatment No.							
	Outside	Inside	Duct	311	312	321	322	323	324	325	326
9/15	62	63	63		55	73	60	57			
9/20	61	65	67		59	72	62	61			
9/25	79	71	81		73	71	59	61			
9/30	81	68	81	79	70	75	60	62	63	63	65
10/ 5	61	73	62	63	63	74	60	60	62	62	61
10/10	67	79	69	63	64	66	54	56	55	56	59
10/15	66	71	62	58	65	69	60	58	58	60	57
10/20	56	66	56	54	55	67	55	57	56	56	54
10/25	50	62	53	53	53	62	52	55	53	53	53
10/30	46	57	48	47	48	57	46	49	47	47	46
11/ 4	48	58	49	48	50	45	46	47	47	47	46
11/ 9	54	61	52	48	51	57	47	46	46	47	46
11/14	47	57	47	46	46	55	45	46	45	45	45
11/19	40	53	45	43	43	53	44	45	44	45	43
11/24	41	53	43	39	43	49	39	39	39	39	39
11/29	35	48	37	33	36	46	34	36	35	34	35
12/ 4	27	46	37	34	34	44	34	35	35	35	35
12/ 9	33	48	37	37	37	46	36	35	35	36	36
12/14	28	45	37	34	34	42	33	34	33	33	34
12/19	29	40	34	36	36	42	35	35	35	35	35
12/24	23	43	35	33	33	40	33	34	34	33	35
12/29	34	45	37	35	35	42	34	35	34	34	35
1/ 3	27	43	36	34	35	42	34	35	34	34	35
1/ 8	25	44	34	35	34	42	34	34	34	34	34
1/13	19	31	33	32	30	42	32	34	32	33	33
1/18	34	35	35	36	35	42	34	33	32	33	33

Figure 11. The flail topper designed by the Agricultural Engineering Department, University of Idaho, in use during the 1963-64 season.

1963-64 Results

The onions were removed from storage from January 30 to February 3, 1964. Results are recorded in Tables 15 and 16 and summarized in the following paragraphs:

Rots. Incidence of rots (Table 15) in all treatments was much less than in previous years. This probably indicates that atmospheric conditions for curing and storing onions were more favorable this year than in previous years. Onions topped by the University flail topper showed a significantly higher percentage of rots than most of the other treatments. Onions topped by the onion harvesting machine (Airflo Co.) or by hand and stored in tote boxes showed significantly lower rotting losses than those stored in bulk or in crates, except where the potato loader was used. Even here the losses were surprisingly low. Onions stored in crates showed significantly more rots where hand topped than where machine topped, while machine-topped bulbs stored in bulk were statistically just as good as machine-topped bulbs stored in crates.

Sprouts. Sprouting (Table 15) was not a factor of quality or condition this year.

Cuts. Bulbs topped by the University beater showed a significantly higher percentage of cuts than those from any other method of topping. This helps to explain why this treatment showed a high rot incidence also, because it is quite likely these bulbs had

more undetected bruises as well as the higher percentage of cuts. Significant differences in percentage of cuts exist between some of the other treatments. All losses from this source were commercially negligible.

Scale color and scale retention. Table 16 indicates that hand-topped bulbs were darker in color than machine-topped bulbs, except for one lot of hand-topped bulbs stored in tote boxes. No explanation of this fact can be given. Although there were significant differences in scale retention, these differences were not always consistent with previous results.

Firmness. Significant differences in bulb firmness can be noted in Table 16, but again there is no consistent pattern to differentiate machine vs. hand topping or bulk vs. crate storage. Under certain circumstances, some of which are still unknown, each treatment showed advantages for degree of firmness.

Bulb rooting and stem plate proliferation. Significant differences exist between some treatments, but the reasons for these differences seem to be beyond the comparison of method of topping or type of storage.

Table 15. Performance in storage of Yellow Sweet Spanish onions stored in bulk and containers, after different curing and topping schedules, Parma Branch Station, 1963-64.[1]

Treatment No.	Treatment	% U.S. No. 1	% Rots	% Sprouts	% Cuts
312	Bulk Bin, 8x8x10 (Machine-topped)	76.13 d	4.98 bc	0	0.30 bc
321	Tote Box (3) (Hand-topped)	82.24 abc	2.16 de	0	0.20 bc
322	Tote box (3) (Hand-topped)	85.35 a	2.66 cd	0	0.00 c
323	Tote box (3) (Flail-chopper)	83.26 abc	7.44 a	0	1.41 a
324	Tote box (3) (Machine-topped)	84.04 abc	2.12 de	0	0.21 bc
325	Tote box (3) (Machine-topped)	83.46 abc	0.32 e	0	0.41 bc
326	Tote box (3) (Hand-topped)	85.16 ab	4.19 bcd	0	0.06 c
341	Crates, check (Machine-topped)	80.66 bc	3.49 cd	0	0.75 b
351	Crates, check (Hand-topped)	79.84 cd	5.95 ab	0	0.00 c

[1]Letters following numbers denote statistical significance according to Duncan's Multiple Range test. Means followed by letter "a" are significantly different from those not having "a", those followed by "b" are significantly different from those not having "b", etc. ($P \leq .05$)

CLIMATOLOGICAL ANALYSIS

An analysis was made of climatological data of temperature and rainfall at Parma for 30 years, using records from the U. S. Weather Bureau. Average maximum temperature, average minimum temperature, average mean temperature and the percent chance of obtaining various amounts of rainfall were calculated for each week of the year. This information for the period of August through April is summarized in Figure 12. The chance of precipitation increases about September 15 and again about October 5. Onions to be cured in storage should be harvested when there is the least chance of rain damage. If harvesting can be accomplished in September, suitable drying conditions would usually exist for curing onions in storage through October. Under unfavorable conditions, heated air could be used to assure proper curing (8, 10).

The dotted line represents the desirable temperature of the onions during the curing and storage periods. By careful control, it would normally be possible to begin cooling the onions during October and achieve a storage temperature of 33 to 35F before December 1.

This information should be used as a guide only. Actual conditions will vary significantly from year to year, and the procedure should be modified according to existing conditions.

Table 16. Effects on color, scales, firmness, roots and stem plate proliferation of Yellow Sweet Spanish bulbs stored in bulk and containers after different curing and topping schedules, Parma Branch Station, 1963-64.[1]

Treatment No.	Treatment	Color[2]	Scales[3]	Firmness[4]	Roots[5]	Proliferation[6]
312	Bulk Bin, 8x8x10 (Machine-topped)	3.7 b	3.1 c	3.9 a	3.9 a	3.13 bc
321	Tote Box (3) (Hand-topped)	3.9 a	3.0 c	3.7 ab	3.7 ab	3.26 abc
322	Tote box (3) (Hand-topped)	3.8 ab	3.0 c	3.5 bc	3.6 ab	3.07 c
323	Tote box (3) (Flail-chopper)	3.9 a	3.8 a	3.7 ab	3.9 a	3.53 a
324	Tote box (3) (Machine-topped)	3.3 c	3.1 c	3.9 a	3.9 a	3.40 ab
325	Tote box (3) (Machine-topped)	3.2 cd	3.1 c	3.6 ab	3.9 a	3.53 a
326	Tote box (3) (Hand-topped)	3.3 c	3.0 c	3.3 bc	3.8 ab	3.07 c
341	Crates, check (Machine-topped)	3.0 d	3.0 c	3.2 c	3.4 b	3.20 bc
351	Crates, check (Hand-topped)	4.0 a	3.5 b	3.5 bc	3.1 c	3.00 c

[1]See footnote Table 15.
[2]Color: 1, light straw; 2-4, intermediate; 5, dark yellow or brown.
[3]Scales: 1, very loose; 2-4, intermediate; 5, very tight.
[4]Firmness: 1, soft; 2-4, intermediate; 5, very firm.
[5]Roots: 1, pronounced root growth; 2-4, intermediate, 5, no root growth.
[6]Proliferation: 1, proliferating badly, all specimens showing proliferation, 2-4, intermediate; 5, no proliferation.

CONCLUSIONS

Storage tests were conducted on Yellow Sweet Spanish onions cured in the field and cured in storage. These onions were stored in bulk bins, in tote boxes and in sacks and crates stacked on pallets. Treatments included (1) hand-topping, field-curing; (2) hand-topping, curing in storage; (3) machine-topping, field-curing; (4) machine-topping, partial field-curing, and (5) green, untopped, curing in storage. From these tests the following conclusions were drawn:

1. Yellow Sweet Spanish Onions can usually be harvested early enough for curing with forced ventilation to avoid adverse effects on storage quality resulting from rain and cold weather frequently encountered when present field-curing methods are used.

2. In-storage curing can normally be accomplished with forced ventilation using unheated air.

3. If harvesting can be completed in September, average weather conditions permit 4 to 6 weeks of in-storage curing when the mean air temperature is 50F or higher. The storage temperature can then be gradually reduced to 33 to 35F before December 1. The onions can be held in storage until early spring or an intervening favorable market.

4. Depth of bulk storage for the Yellow Sweet Spanish type onion is limited to less than 8 feet. Excessive damage from pressure bruising will result at greater depths. Additional work should be considered to elaborate on methods for handling bulk onions, especially for unloading onions from bulk storage.

5. Tote boxes appear to offer an effective method of handling onions. Mechanization is possible with existing equipment and delivery of high quality onions can be maintained. This method will require special boxes and a system of connecting air ducts to provide forced ventilation for curing and storing. However, since the boxes will not be used for shipping, they may be reused year after year.

6. Although onions cured with green tops had better scale retention than when machine-topped, there is danger of excessive neck rot developing during storage. Heated air during the curing period might have circumvented this problem by drying the tops more rapidly. Onions stored with green tops require more storage space.

7. Significant differences were noted between treatments in such quality criteria as scale color, scale retention, bulb firmness, bulb rooting and stem plate proliferation. These differences

were not consistent from year to year. For example, in 2 of the 3 years, hand-topped bulbs showed darker color and better scale retention than machine-topped onions; in 2 of the 3 years, hand-topped bulbs were firmer than machine-topped bulbs. Differences in bulb rooting and stem plate proliferation were noted between many of the treatments. Additional research is needed to determine the cause of such differences.

8. A fairly effective job of topping onions stored with tops attached can be achieved by an air-flow type topping machine after the onions are removed from storage. However, a substantial portion of the leaves were removed during storage and in unloading the onions. The remaining top was not always sufficient to help position the onion bulb for the topping equipment, leaving a substantial stub.

9. Air flow rates used in these tests varied from 0.8 to 1.7 cfm per cubic foot of onions. The rate of air flow does not appear to be a critical factor within these limits. The recommended rate of 1.0 to 1.5 cfm per cubic foot of onions should be adequate for topped onions when average climatic conditions prevail. If unusually cold, wet weather is encountered during the curing period or if harvesting is delayed, it may be necessary to add heat to promote good curing.

10. Machine damage in topping during the first two years of this experiment was significant when compared to hand-topping, but later modifications reduced injuries. Successful onion storage depends on good quality bulbs to begin with. Special attention is required to prevent injuring and bruising bulbs during harvesting, loading and conveying. Some helpful practices include: reduce belt and chain conveyor speeds; eliminate corners from right angle turns on conveyors and keep the distance of fall (i.e. conveyor to truck) as short as possible.

11. Since curing is a drying process, some weight loss will result. With in-storage curing, the weight loss amounted to about 5 percent. This may vary depending on the stage of onion maturity. Weight loss during the storage period will be considerably less, but it depends to some degree on storage temperature and relative humidity. Total weight loss observed during curing and storage in this research was 6 percent.

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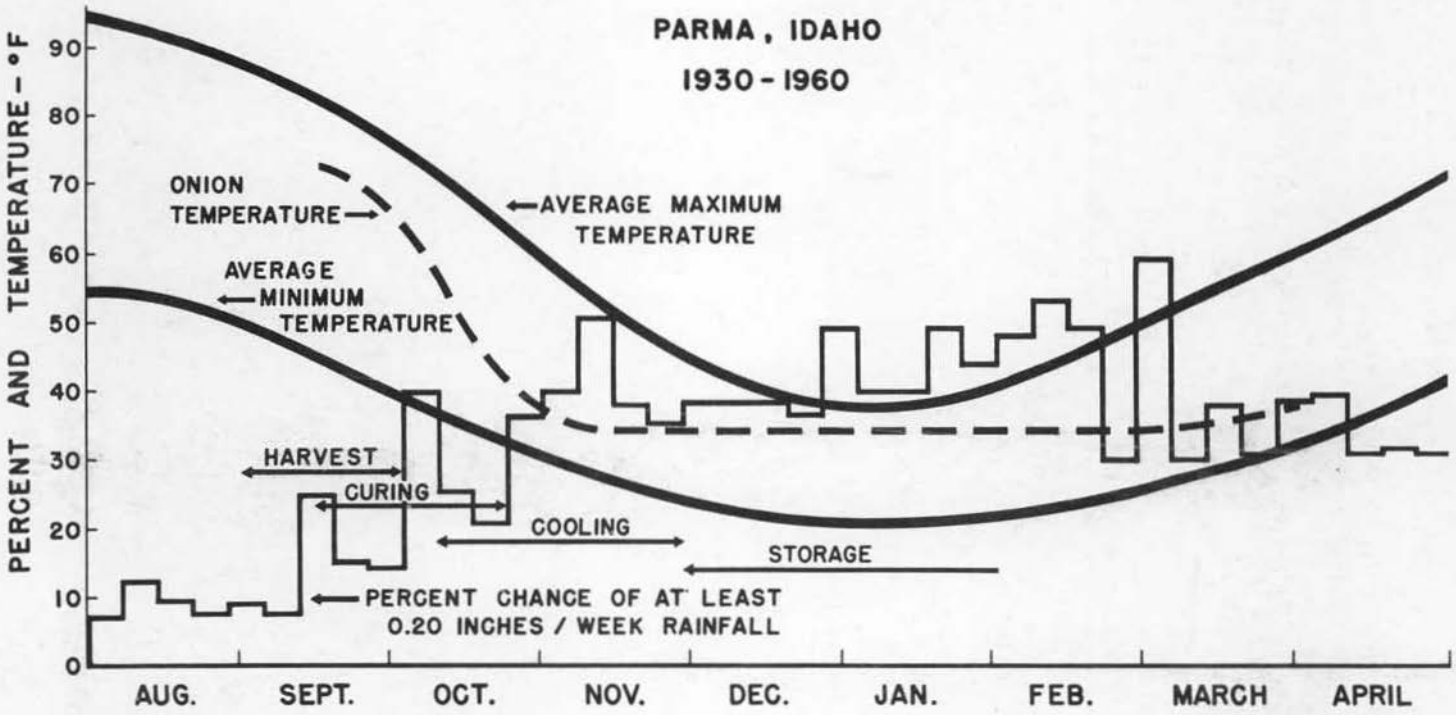

Figure 13. Climatological analysis of weather data recorded by the U. S. Weather Station, Parma, Idaho, from 1930 through 1960.