T H E S I S

O N I O N C U R I N G A N D S T O R A G E

I N V E S T I G A T I O N S

Submitted by

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Earl James Allen

ENTITLED "ONION CURING AND STORAGE INVESTIGATIONS"

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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INTRODUCTION

Commercial onion production in Colorado has become of major importance to the vegetable industry of the state and during the past 10 years has increased from a small acreage to approximately 7,000 acres in 1929. The Western Slope district, previous to that time, held the lead in total production. However, in that year the Arkansas Valley shipped out 2,508 as compared to 1,328 carloads from the Western Slope. Production in the Arkansas Valley increased from 183 carloads in 1927 to the above named figures in 1929. The Northern Colorado section shows less increase than the other two districts and has not developed to the same extent.

The production and price figures, secured from information furnished by the U. S. Bureau of Agricultural Economics and shown in Tables I and II, show very clearly the rapid growth of the onion industry in Colorado and its value to the growers.

Due to the recent development of the onion industry in the Arkansas Valley, growers were not familiar with standardized practises necessary to properly grow, cure, harvest and store their onions. Differences of opinion existed, and still exist, in regard to the most profitable methods of curing and storing.

The first few years of development of the industry

Table I. Acreage, production and shipment of Colorado onions.

Year	Acreage	Yield per acre (bu)	Production ,000 bu.	Total carlot shipments	Shipments by districts: W. Slope	Ark. Val.	N. Colo.
1920	760	340	258	150	128	0	22
1921	1,300	300	390	447	391	0	56
1922	1,900	280	532	651	570	13	68
1923	2,620	250	655	928	839	8	81
1924	3,410	270	921	1,064	944	10	110
1925	3,520	325	1,144	1,809	1,743	15	51
1926	3,700	275	1,018	1,758	1,411	91	256
1927	4,300	320	1,376	1,460	1,172	183	105
1928	3,700	310	1,147	2,244	1,231	743	270
1929	7,000	369	2,586	4,019	1,328	2,508	186

Table II. Average price per bushel, value per acre.

Year	Price per bu. $	Total Value $	Value per acre $
1920	.72	186,000	244.73
1921	.53	597,000	460.00
1922	.52	277,000	145.00
1923	1.08	707,000	269.00
1924	.58	534,000	156.00
1925	.78	892,000	253.41
1926	.50	509,000	135.57
1927	.45	619,000	144.00
1928	1.42	1,629,000	440.00
1929	.42	1,097,000	156.57

found losses in storage a negligible factor, but with each succeeding year, losses became greater until in the present season (1930-1931) they ranged from 15 to as high as 60 and 70 percent.

In most cases, losses in storage are caused by infection of rot organisms such as neck-rot (Botrytis allii), Fusarium bulb rots (Fusarium species) and purple blotch bulb rot (Macrosporium porri). Other causes of storage losses are sprouted bulbs and shrinkage due to a decrease in moisture content.

Such losses are often large enough to preclude any possibility of the grower realizing a profit on his stored crop. It was with a realization of the growing seriousness of the situation, and also in response to a request from the growers, that the Colorado Agricultural College established a horticultural sub-station at Rocky Ford with the object of assisting the growers in working out their production and storage problems. This work was first started in 1929. The data presented in this paper were secured during the years 1929 and 1930.

The purpose of the investigations reported herein was to determine, if possible, practical methods and procedures whereby losses of onions in storage might be reduced to a minimum.

REVIEW OF THE LITERATURE

Investigations in regard to losses of onions in storage have covered a long period of years. Work on the nature and control of the diseases causing storage rots, on cultural methods affecting the susceptibility of bulbs to infection, on methods of harvesting and curing and on conditions in storage has determined that all these factors must be considered in reducing storage losses. The writer in reviewing the literature has included only those investigations which have a direct bearing on conditions which are found in the Arkansas Valley. Investigations concerning the control of diseases such as smut, blight, mildew and others which have not as yet appeared in the Valley, or which do not affect stored onions, were not abstracted in the review of literature.

Halstead (1) reported a botrytis disease of onions in 1890. He suggested that the onions be harvested in a dry condition and stored in a cool place. He also suggested that sprinkling the onions with air-slaked lime might check the spread of the disease in storage.

Clinton (2) reported in 1904 that the wet seasons of 1902 and 1903 were probably responsible for the large losses in storage, as the year 1904 was much drier and losses were correspondingly less. He observed that the white varieties of onions were much more susceptible to stem rot (Botrytis species) than the darker skinned types.

Spraying with a bordeau mixture did not give definite results, due to the slight amount of infection during the season of 1904. No difference was found in storage in the keeping qualities of sprayed and unsprayed onions.

Garcia (3) observed in 1910 that wet weather just before and during harvest caused large losses from rotted bulbs.

Bennett (4) found that the greatest difficulty in keeping onions in storage was the tendency of the bulbs to sprout. He recommended that storage houses should be frost proof and as dry as possible. If onions were kept dry and near the freezing point they could be kept until February or March.

Humbert (5) reported losses in storage ranging from 15 to 75 percent. He determined that the neck-rot spores found on crates in April and May after the storage season were viable. He also determined that spores from refuse piles two and three years old were viable. He recommended ventilation and fumigation of newly topped bulbs as means of control. According to his figures, fumigation with formaldehyde materially reduced the amount of disease. His observations indicated that the rot organisms were very apt to gain a foot-hold in the onion at the time of topping and he suggested that the onions be allowed to dry thoroughly before being topped.

In a report dealing with the onion industry of the Connecticut River Valley in Massachusetts, Cance, Machmer,

and Reed (6) stated that onions which are to be placed in storage will keep better if pulled somewhat green and allowed to cure in storage. They also reported that onions might be left on the ground for several days after pulling if not topped but that topped onions would not keep well if left on the ground for any length of time. Experienced growers of the region stated that onions kept in storage just as well if not better when the bulbs were not topped.

Munn (7) reporting in 1917 gave a complete history and description of the causal organism of the neck-rot disease and named the fungus Botrytis allii. He found that the neck-rot disease of onions occurred in every principal onion district in the United States, causing heavy losses in storage and frequently to the growing crop. He describes the disease as follows:

"The most striking signs of the disease are to be found in the storage houses where the causal fungus appears as a mass of sclerotia at the necks of onions. However, these may cover part, or all, of the individual bulbs. The smoke grey covering of fungus growth commonly recognized by onion growers as 'grey mold' is another striking sign of the disease."

According to Munn's observations infection occurs in the field through the leaves and necks. The rot either develops in the field or later in storage when conditions are more favorable. The bulbs may also become infected from the soil. The factors he found favorable to infection and the occurrence of the disease are given below.

"(1) Immaturity and imperfect curing of the bulbs; (2) the application of commercial fertilizers late in the season or in incorrect proportions; (3) the application of

large quantities of stable manure before planting; (4) poor air drainage in the field; and (5) high humidity, high temperatures and poor ventilation in the storage house."

Bulbs with large thick necks were found to be very susceptible to the disease.

As control measures Munn recommended the following practises:

"(1) the tops should be well ripened and shriveled before pulling; (2) the onions should be well cured and stored in a house with good ventilation; (3) temperature in the storage house should be kept as near freezing as is possible and humidity should be low; (4) sanitation should be practised in field and in storage; (5) bruising of the bulbs should be avoided; and (6) selection for good neck type and earliness should be practised."

Experiments showed that the soil type did not affect the degree of infection. Short topping of bulbs did not affect the keeping quality of onions. Spraying with a bordeau mixture resulted in 4.4 percent less loss in storage.

Halligan (8) reported that, if onions were allowed to stay too long in the ground after maturing, especially during moist weather, a second growth might start which would make curing and drying of the bulbs more difficult.

Sayer (9) recommended that onions which are to be stored in pits be stored with the tops left on.

Beattie (10) stated that onions to be stored should be well ripened and thoroughly cured; that the essentials for successful storage are plenty of ventilation, storing in small quantities, a comparatively low temperature, dryness and safety from actual freezing.

Under California conditions Rogers (11) recommended

that onions be cured in the field from four to seven days, then topped and placed in storage.

Jones (12) discussed the factors related to onion dormancy and suggested that oxygen was the limiting factor in the growth of the bulbs. This opinion was derived from the fact that wounding or cutting the bulbs resulted in sprouting. In his work, the amount of water contained in the bulb did not seem to influence growth.

Boswell (13) in continuing the studies on onion dormancy begun by Jones (12) found that wounding of onion bulbs by transverse cuts resulted in marked stimulus of growth. The closer the cut was made to the growing regions of the bulb, without injury to those parts, the greater was the effect on growth stimulation. The stimulus to growth seemed to be associated with increased availability of oxygen rather than a wound stimulus. Freezing, etherizing and exposure to sunlight resulted in less growth than with the check lots of bulbs.

In further studies Boswell (14) found that early maturing bulbs started growth in storage less readily than late maturing bulbs and that losses from decay were less in the early maturing bulbs. Storage at temperatures near freezing resulted in a minimum amount of loss from decay. Variations in temperature from low to high resulted in greater growth than in bulbs held at the higher temperature.

Yeager (15) suggested a temperature of around 32°

Fahrenheit and a dry atmosphere for the storage of onions. He found that normally matured bulbs kept best. He reported that in 1921, when the maturity of bulbs was hastened by a dry fall, it was almost impossible to keep the onions from sprouting. He also observed that in normal years the early flat varieties failed to keep.

Irwin and Harter (16) called attention to the fact that in the Pleasant Valley district of Iowa that the wet weather during the harvesting season of 1915 resulted in the loss of the major portion of the onion crop from rot.

Walker (17) in studying varietal resistance to rot infections found that the dark skinned type of onions showed much greater resistance to disease than did the white varieties.

In further studies Walker and Lindegren (18) found that resistance to neck-rot disease was due to a soluble toxin found in the outer colored scales. Control experiments showed, that with inoculations directly into the succulent tissue (thus eliminating the influence of the soluble toxins in the dry outer scales), infection occurred with approximately equal rapidity in colored and in white bulbs. The writers suggested that the occasional epiphytotics in colored varieties might be due to particular conditions at harvest time. Such a condition as premature topping might expose succulent tissue to the attack of the disease. Insect injuries and openings in the stem plate

might provide other modes of entrance of the disease in colored bulbs.

In discussing the relation of environment to the control of fusarium rot (Fusarium species), Walker and Tims (19) stated that holding the bulbs in an atmosphere of high relative humidity greatly increased the percentage of infection in inoculated bulbs. Development of the disease in storage was accelerated by higher temperatures.

Link and Bailey (20) reported that the fusarium bulb rot of onions was found in practically all onion growing sections of this country. In their report they gave a description of the disease in the bulbs and plants and stated that colored and white varieties were equally susceptible.

In further work on the mycelial neck-rot of onions, Walker (21) found that the state of maturity of onion bulbs when the tops are removed has a direct bearing on the amount of infection. Topping onions of the Red Globe type, when the neck tissue was still succulent, resulted in doubling the amount of infection as compared to onions which had properly matured tops. In the case of colored varieties, removal of the tops at pulling time as compared to allowing them to remain on the bulbs after harvest, resulted in greater infection. However, with white bulbs, very little difference resulted.

Artificial curing of onion bulbs sufficient to cause desiccation of neck tissue within two or three weeks

after harvest resulted in material decrease in the amount of disease.

In another article on the Botrytis neck-rot disease of onions, Walker (22) gave a description of the disease and gave recommendations for its control. He stated that there are three closely related but distinct neck-rot diseases of onion bulbs; grey-mold neck-rot (Botrytis allii), mycelial neck-rot (Botrytis byssoidea) and small sclerotial neck-rot (Botrytis squamosis). Infection and decay of bulbs infected by these organisms are reported as being favored by temperatures below 68° and above 59° Fahrenheit.

Field observations in the Middle West over a period of years showed Botrytis byssoidea to be most prevalent during seasons in which the temperature was below normal and the rainfall above normal.

Infection by Botrytis allii and Botrytis byssoidea was reported to take place more rapidly when the neck tissue is succulent at the time the bulbs are topped than when the tops are dried out. When harvested under comparable conditions, bulbs with mature tops showed less infection than bulbs with immature tops. Harvesting the bulbs with tops intact resulted in slightly less infection than was the case when the tops were removed at harvest time.

Colored varieties were less subject to attack than white varieties, although the disease proceeds with equal

rapidity in either case after infection once occurs. Walker suggested that the water soluble toxins in the dry outer scales and neck tissues of the colored bulbs aids materially in excluding the organisms.

He further stated that control might be effected in a large measure by artificial curing of the bulbs after harvesting, or by other rapid curing methods.

In discussing farm practises in relation to storage diseases, Walker (23) recommended that sanitary measures be employed, and that all old tops, old bulbs, and other refuse should be burned or buried. Infected bulbs should not be stored. He stated that white varieties will not keep long and, as is the case with the Bermuda onion, should be promptly sold. Sun-burn, freezing and bruising will give bacteria a chance to start, particularly under moist conditions. According to his observations, prevailing rainy weather at harvest time and during the curing period usually leads to heavy rot losses in storage.

Harmer (24) reported that the development of neck-rot in onions is largely due to two factors at harvest time; first, the state of maturity of the bulb neck tissue and, second, weather conditions. He stated that immature or succulent neck tissue is very conducive to infection by the neck-rot fungus and that wet weather during the curing period usually results in an increase in the amount of decay. He found that variations of temperature in storage tended to hasten sprouting. He recommended the

following practises as control measures:

"(1) Cultural operations should be conducted so as to reduce scallions to a minimum. (2) Late growth should be avoided. And (3) curing should be hastened by every means possible."

He reported that rapidly cured bulbs were rarely infected and suggested artificial curing wherever the procedure was practical.

Cance and Fiske (25) stated that early onions are not storable and that it is important that the onions be kept dry.

Variety trials at the Utah Station (26) showed great variation in the keeping qualities of onion varieties. The Australian Brown was found to be the best keeper followed by the Valencia (Sweet Spanish), Yellow Globe and Southport Yellow Globe in the order named.

In studying the effects of freezing on onions, Wright (27) found that the average freezing point of onions was about 30° Fahrenheit. He stated that onions may be undercooled below their freezing points without freezing, if not moved or handled; and that onions with only the outermost scales injured by freezing may as a rule be salvaged, if allowed to dry out. Such onions, if left in a damp storage or without sufficient ventilation, will soon start to decay.

LeClerg (28) recommended grading of onions before placing them in storage, removing all split onions, scallions and doubles, as they are more susceptible to neck-

rot infection. He suggested quick curing and storing in a dry house as preventive measures.

Angell (29), in his studies on purple-blotch of onions, found that the disease is caused by a fungus which he calls Macrosporium porri. Since the nature of the development of this disease is somewhat similar to that of neck-rot, he recommended that the same control methods be used. Among these were thorough and rapid drying of the bulbs and a low temperature in storage. Spraying with a bordeau mixture did not control the disease on the plants.

The review of the literature discloses some differences of opinion regarding the proper state of maturity at which to harvest onions, and whether or not early maturing bulbs keep better than late maturing bulbs.

Cance, Machmer and Read (6) reported that growers in the Connecticut River Valley harvest their onions while still somewhat green, if the bulbs are to be placed in storage. But Munn (7), Beattie (10), Walker (21) and Harmer (24) have all stated that onions should be well matured before harvesting.

In regard to early and late maturing onions, Boswell (14) found that early maturing bulbs sprouted less in storage and suffered less decay than late maturing bulbs. However, Yeager (15) reported that onions which were matured early as a result of dry weather did not keep well. He also stated that the early flat varieties were poor

keepers.

Perhaps the most significant point brought out in the investigations is in regard to the condition of the tops of the onions when they are removed.

Walker and Lindegren (18) suggested that premature topping, which through wounds might expose succulent tissue to attack of Botrytis allii, could be responsible for disease infection. In a later investigation, Walker (21) reported that topping onions of the Red Globe type, when the neck tissue was still succulent, resulted in doubling the amount of infection as compared to onions which had properly matured tops; and that, in the case of colored varieties, removal of the tops at harvest time, as compared to allowing them to remain on the bulbs after harvest, resulted in greater infection. Walker verified these conclusions in further work on the neck-rot disease of onions (22).

Harmer (24) reported that the development of neck-rot in onions is largely due to two factors, one of which was the state of maturity of the neck tissue of the bulbs at the time of harvest. He stated that immature or succulent neck tissue is very conducive to infection by the neck-rot fungus.

Munn (7) found that bulbs with large thick necks were very susceptible to neck-rot. This was probably due to the fact that the necks of such bulbs remain green for a long period of time and topping leaves succulent tissue

exposed.

Humbert (5) observed that rot organisms were very apt to gain a foothold in the onion at the time of topping and suggested that the onions be allowed to dry thoroughly before being topped.

Conditions in the Arkansas Valley differ greatly from those found in the onion districts of the northern and northeastern states. Climatic factors are most typical of these differences.

In Colorado, rainfall is insufficient to produce profitable onion crops. Irrigation is depended upon to supplement, and, in some years, to completely replace rainfall. This condition results in cultural practises peculiar to irrigated districts.

In the humid districts of the northern and eastern onion growing sections, rainfall is depended upon for the entire water supply. The prevalence of rains in those districts during harvesting and curing periods necessitates the curing of onions undershelter. While in Colorado, the normal clear and dry weather during the curing seasons enables the growers to cure their onions in the field. For these reasons and because storage houses may be more easily kept free of moisture in our dry climate, as compared to humid sections, cultural methods, harvesting and curing practises and storage practises recommended for the eastern districts may not be applicable or desirable under Colorado conditions.

In the Arkansas Valley, the Sweet Spanish type of onion is grown almost exclusively. This onion is a large, mild, thin skinned type with a high yielding ability and requires a long growing season in which to properly mature. In the eastern districts, the varieties grown produce smaller, stronger flavored and thicker skinned bulbs and mature in a shorter growing season.

As a result of the differences shown above, it was not possible to accept, as final for Colorado conditions, the results of investigations conducted under entirely different climatic, cultural, harvesting, curing and storage conditions. For this reason the work was not centered on any one phase brought out by other investigators but was made to cover several phases of the problem. In this manner, a closer check could be obtained on the influence of factors, peculiar to this region, upon storage losses, and definite points of attack could be determined for continued work.

STATEMENT OF THE PROBLEM

The object of the following investigations was to determine practical methods of reducing storage losses through variety and strain trials, improved cultural practises, better harvesting and curing methods and more desirable storage conditions.

MATERIAL AND METHODS

The material for the experiments consisted of field grown onions subjected to different cultural, harvesting, curing, and storage treatments. In connection with this work, variety and strain trials were conducted to compare keeping qualities. The onions were weighed in crates after harvesting and before being placed in storage. Weighings were made on platform scales, checked by standard weights. The onions were stored in uniform-sized slatted crates holding an average of 70 individual bulbs.

Losses in storage were determined at the close of the storage seasons. Moisture losses were determined by the differences in weight at the start and at the end of the season. Rot and sprout losses were determined by grading out rotted and sprouted bulbs and weighing those discarded.

The onions used in comparative trials were subjected to identical conditions of growing, harvesting, curing and storing, except for the method of treatment under consideration.

The onions were grown under irrigation on land leased by the Horticultural Department at Rocky Ford during the seasons of 1929 and 1930.

The storage house was constructed of adobe bricks placed on a concrete foundation. The floor was covered with a four inch layer of cinders placed on the dirt base.

The storage house was built with two compartments, each 40 by 20 feet in size, with a ten foot ceiling insulated with Celotex. The partition wall was built of adobe bricks, with a large door between the compartments constructed of three layers of wood. Outer doors were constructed in the same manner. The windows were made with a single thickness of glass.

The north compartment of the building was built with one large and one small outside door, four windows, and four ventilators placed on the foundation of the building. The south compartment was similar in each respect save that no bottom ventilators were provided.

Temperature and humidity records in each compartment were obtained by means of hydro-thermographs corrected by means of a wet and dry bulb thermometer and a standardized thermometer. Corrections were made at intervals of two or three weeks during the storage period.

Weather conditions during the curing period of 1929 were almost ideal. Fair days and sunshine prevailed throughout the period. But during the 1930 season the weather was quite the opposite. Cloudy days were common and two rains were recorded. Table III shows the daily precipitation during the two curing periods.

The general increase in rot losses recorded for the 1930 season, as compared to the 1929 season, may be attributed in part to the wet weather during the curing season..

Table III. Daily precipitation records at Rocky Ford, September 1 to October 25, 1929 and 1930

Sept.	1929	1930	Oct.	1929	1930
1			1		.23
2			2		T
3			3		.80
4	T*		4		
5		.73	5		.18
6	.09	.01	6		
7	.70	.28	7		
8	.11		8		
9			9		
10	.01		10		.65
11			11		
12			12		
13		.04	13		
14			14		
15			15		
16			16		
17			17		
18			18		
19			19		
20			20		
21			21		
22			23		
23			24		
24			25		
25			26		
26					
27					
28					
29	.02				
30		T			
Total	.93	1.06		0.0	1.86

Total September 1 to October 25, 1929 0.93
" " " 1930 2.92

RESULTS OF THE INVESTIGATIONS

Comparison of the Keeping Qualities of Onion Varieties and Strains

Variety trials. The varieties were grown under similar conditions, being planted on the same day and receiving the same care throughout the growing season. Harvesting and curing methods were identical. The results obtained from these trials are given in Tables IV and V.

The Australian Brown, Ohio Yellow Globe, Yellow Globe Danvers, Southport Yellow Globe and Sweet Spanish varieties were the best keepers in the order given, followed by Mountain Danvers, Ailsa Craig, Prizetaker, Gibraltar and Denia.

The best keeping onions were all of varieties with dark yellow or brown skinned bulbs. Walker and Lindegren (18) have reported that the outer scales of dark colored onions contain a soluble toxin which inhibits the growth of the neck-rot organism and that colored varieties keep better in storage.

In these trials, the poorer keeping onions were of the straw colored type. The Sweet Spanish, which is intermediate in color, was found to be a moderately good keeper.

Comparisons at the Utah Station (26) showed that the Sweet Spanish (Valencia) ranked next to the Australian Brown variety in keeping quality. The Yellow Globe and

Table IV. Comparison of keeping qualities of onion varieties.

Year	Variety	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
1929	Australian Brown	0.0	*	1.65	1.65
	Mountain Danvers	0.0		2.91	2.91
	Ohio Yellow Globe	0.0		2.92	2.92
	Sweet Spanish or Valencia	0.27		3.31	3.58
	Gibraltar	0.0		4.48	4.48
	Yellow Globe Danvers	0.0		4.88	4.88
	Denia	0.0		6.39	6.39
	Yellow Globe	0.0		7.1	7.1
	Ailsa Craig	0.0		7.89	7.89
	Prizetaker	0.0		20.13	20.13
1930	Ohio Yellow Globe	0.0	1.8	.9	2.7
	Australian Brown	0.0	2.0	.76	2.76
	Yellow Globe Danvers	1.0	1.5	1.5	4.0
	Southport Yellow Globe	.97	3.0	3.6	7.57
	Sweet Spanish or Valencia	9.5	3.0	1.0	13.5
	Mountain Danvers	4.7	5.3	12.2	22.2
	Ailsa Craig	18.0	3.6	1.0	22.6
	Gibraltar	31.5	3.6	4.7	39.8
	Denia	36.4	4.2	7.9	48.5

*Loss in moisture was not determined in 1929.

Table V. Average total* losses of varieties in storage for the two year period 1929 and 1930.

Variety	Loss in storage (Percentage)
Australian Brown	2.2
Ohio Yellow Globe	2.81
Yellow Globe Danvers	4.44
Yellow Globe**	7.1
Southport Yellow Globe**	7.57
Sweet Spanish or Valencia	8.54
Mountain Danvers	12.55
Ailsa Craig	15.24
Prizetaker**	20.13
Gibraltar	22.14
Denia	27.44

*Loss in moisture was determined only one year (1930).
**Varieties grown only one year.

Southport Yellow Globe, in their trials, ranked below the Sweet Spanish.

Such trials are of value in determining better varieties to use in selection and cross-breeding work with the object of producing an onion of high yielding ability, good keeping characteristics and good quality.

Strain trials. The Sweet Spanish or Valencia onion has been proved by both local experience and by experimental investigations, previously reported upon (30), to be the type best adapted to the Arkansas Valley. The Riverside strain of this variety was selected in order to determine what part breeding and selection played in producing onions of good keeping quality. These trials were conducted in the same manner as the variety trials. Table VI shows the results secured.

As shown in this table, there is a large variation in the keeping qualities of the various strains. This indicates that it is possible by breeding and selecting for a type resistant to storage rots to greatly improve a strain in regard to keeping qualities.

Effect of Cultural Methods on the Keeping Qualities of Onions

Transplanted and field-sown onions. In this project one plot of onions was grown from seed drilled in the field during the month of March. The other plot was grown

Table VI. Strain trials of the Sweet Spanish onion.

Year	Strain	Losses in Storage (Percentage)			
		Rot Loss	Moisture Loss	Sprout Loss	Total Loss
1929	California No. 2	.17	*	3.31	3.48
	California No. 3	.23		3.41	3.64
	California No. 1	.38		3.31	3.69
	Colorado No. 1	.05		7.51	7.56
	Colorado No. 2	.17		9.2	9.37
	California No. 4	.00		12.14	12.14
1930	Colorado No. 2	3.6	2.3	2.6	8.5
	Colorado No. 1	4.8	3.3	1.5	9.6
	California No. 2	7.6	3.3	.2	11.1
	California No. 4.	5.6	3.3	6.5	15.4
	California No. 1	10.8	3.6	1.2	15.6
	California No. 3	12.0	3.8	1.4	17.2
	Imported Spanish	12.5	7.6	2.6	22.7

*Moisture loss was not determined in 1929

from onions which had been sown in plant growing structures and transplanted to the field during the month of April. The transplanted onions matured several days ahead of the field-sown onions and, as a result of earlier harvesting, were allowed to cure in the field a few days longer than the others. Other conditions of harvesting and storage were similar.

The results obtained in this experiment are given in Table VII.

The difference in keeping qualities of transplanted onions as compared to field-sown onions, as shown in Table VII, is so slight as to be negligible. There was less than 1 percent more rot with the field-sown as compared to the transplanted onions. An interesting phase of this project is in the comparison of early maturing with later maturing onions. The transplanted onions matured a week or ten days ahead of the field-sown each year. But there was no great difference in state of maturity at the time of harvest. Due to the conditions under which the experiment was conducted, the only definite conclusion from the work is that there is little difference in the keeping qualities of transplanted and field-sown onions.

Immature and mature onions. In this experiment, onions from seed planted March 20 were compared to onions grown from seed planted May 4. The onions were of the Sweet Spanish type and were from the same strain of seed.

Table VII. Transplanted and field-sown onions.

Year	Treatment	Weight of onions (lbs)	Losses in storage (Percentage)			
			Rot loss	Moisture loss	Sprout loss	Total loss
1929	Transplanted onions	2403	4.66	1.76	.89	7.31
1929	Field-sown onions	2500	5.0	1.8	.66	7.46
1930	Transplanted onions	583	4.9	2.2	10.8	17.9
1930	Field-sown onions	577	3.6	3.3	12.9	19.8
Average for 2 years	Transplanted onions		4.78	1.98	5.84	12.60
	Field-sown onions		4.3	2.55	3.39	13.63

Other than the differences in planting dates, the onions received the same care throughout the growing, harvesting, curing and storage periods. The storage period was from October 10 to February 18.

As shown in Table VIII, green or immature onions kept in storage with much less rot than those that were well matured. There was difference of nearly 10 percent in favor of the immature bulbs. But the decreased loss from rots was more than offset by the increased loss in moisture and green sprouts.

The loss from sprouting, in the case of the immature onions, might conceivably be reduced by a more thorough curing of the bulbs before being topped and placed in storage. The immature onions, when pulled, were still growing at a rapid rate. They were topped the day after pulling while growth was presumably still taking place. It was noticed that green sprouts appeared within a day or two. If the tops had been allowed to remain on the bulbs until all growth had stopped and the bulbs were thoroughly dry, it is supposed that sprouting might have been greatly reduced. In such a case, the smaller loss from rots in the immature onions may well be given further consideration in future trials.

In suggesting an explanation for this decrease in rot loss it is necessary to consider growing conditions. The late planted onions went into the month of August in vigorous growing condition and with new leaves still being

Table VIII. Immature and Mature onions.

1930

Date of planting	Weight of onions (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
March 20	477	15.19	5.03	2.6	22.82
May 4	178	5.8	13.3	38.0	57.1

formed. It was noticed that injury from thrip insects (Thrips tobaci) on these plants was much less evident than upon the earlier planted onions. Further observations revealed that infection from the purple blotch organism (Macrosporium porri) was also much less than was the case with the earlier planted onions.

The connection between thrip insect injury and purple blotch infection has not been determined, although Angell (29) reported that inoculations of onions with Macrosporium porri was accomplished with or without wounding the leaves of the plant. But it is possible that thrip insect injury may facilitate the entrance of the organisms of purple blotch and other diseases into the plant. In such a case, late planting may result in greater plant resistance to attack from thrips, thereby decreasing chances for disease infection. This should permit onions to go into storage with less disease infection. This would, in turn, decrease losses from purple blotch and other storage rots.

Walker (17) suggested that insect injuries may provide a mode of entrance for the neck-rot organism.

Effect of fertilizers. In this project, the fertilizer treatments were applied on each side of the onion rows at a distance of three inches from the plants, just before the first cultivation. The onions were about two inches high at that time. Applications were made at the

rate of 200 pounds per acre, with the exception of triple super-phosphate which was applied at the rate of 100 pounds per acre. The onions were of the Sweet Spanish type and of the same strain of seed. Growing conditions, harvesting methods and conditions in storage were similar. The onions were put in storage on the tenth of October and were graded out February 16.

The effect of fertilizers on the keeping quality of onions in storage, as shown by Table IX, is rather startling. The results from one year's work indicate that onions fertilized with potash or nitrogen produce poorer keeping bulbs than onions grown without fertilizers. Phosphate fertilizer, alone, improved the keeping qualities of the bulbs approximately 2 percent as compared to unfertilized onions.

There was no noticeable difference at time of harvest in the state of maturity of the bulbs. Neither could there be observed any difference in resistance to thrip insect injury or purple-blotch infection. Further trials and closer observations will be necessary to substantiate the results obtained.

Effect of late irrigation. It is customary for growers in the Arkansas Valley to withhold water from the onions for a period of at least three weeks prior to harvesting. The reason advanced for this practise is that the onions are allowed to dry out further and will keep

Table IX. Effect of fertilizers on the keeping qualities of onions.

1930

Fertilizer	Weight of onions* (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
Super-phosphate	232.5	9.4	2.7	0.0	12.1
Check	233.5	8.3	2.9	0.0	11.2
Check	238.5	9.8	3.7	0.0	13.5
Check	233.5	13.9	4.2	0.0	18.1
Average of checks					14.26
3-18-3	238.5	14.8	3.7	0.0	18.5
0-16-6	242.5	17.6	3.9	0.0	21.5
Potassium Nitrate	238.5	20.7	5.0	0.0	25.7
Sodium Nitrate	243.5	25.08	4.5	0.6	30.18
4-12-4	240.5	26.7	4.6	0.6	31.9

* Graded bulbs

better in storage. In this project it was planned to harvest bulbs from plots which had been irrigated from one to four weeks before harvesting. Fall rains, however, made it impossible to secure a period longer than two weeks without water.

Bulbs from plots irrigated one and two weeks before harvesting were given the same curing treatments and placed in the same storage room. The onions were pulled on the same day, topped three days later, cured in the field in crates ten days after topping and kept in storage from October 13 to February 17, when losses in storage were determined. The results of this project are given in Table X.

Contrary to local opinion, the onions irrigated one week before harvesting kept better than the onions which were irrigated two weeks before harvesting.

Influence of Harvesting and Curing Methods on the Keeping Qualities of Onions

Length of field curing. In an effort to determine the number of days required to properly cure onions in the field after pulling and topping, five crate lots of onions were cured in the field in crates from 1 to 21 days after topping. The bulbs were topped 3 days after being pulled. The onions were of the Sweet Spanish type and were from the same strain of seed. The project was carried on for two years (1929 and 1930). The onions were weighed as soon as

Table X. Effect of late irrigation on the keeping qualities of onions.

1930

Treatment	Weight of onions (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
Irrigated 1 week before pulling	478	12.8	6.4	3.4	22.6
Irrigated 2 weeks before pulling	424.5	18.0	6.1	3.1	27.2

topped and losses in storage were determined at the close of the storage season. The data from this experiment are given in Tables XI, XII and XIII.

The results from two years' work on the length of time necessary to properly field cure onions which are topped two or three days after pulling are inconclusive. Apparently, there is no direct correlation between length of field curing and losses in storage, when, as stated above, the onions are topped two or three days after pulling. Averaging the losses in onions cured 1 to 5, 6 to 10, 11 to 15 and 16 to 21 days shows a difference of only 1.06 percent between the low and high groups. The curing periods of one to five days resulted in the lowest losses. The greatest loss was in the curing periods ranging from 16 to 21 days.

Curing in the field and curing under a shed. In eastern states where rains are common during the curing season, onions are often cured under sheds before being placed in storage. It was thought that this method of curing might improve the keeping qualities of onions grown in the Arkansas Valley. A comparison of onions cured under sheds and in the field was the object of this experiment, which was carried on for two seasons. The lots of onions consisted of ten crates each, in each instance. The onions were of the Sweet Spanish type and from the same strain of seed. The onions were pulled and allowed to cure in the

Table XI. Length of field curing periods and results in storage.

1929

Days cured in field	Weight of onions (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
1	227	9.91	6.82	6.60	23.33
2	226	6.41	5.3	4.42	16.13
3	225	2.22	5.33	2.44	9.99
4	225	2.89	4.91	2.39	10.19
5	224	4.93	4.72	5.63	15.28
6	221.5	5.64	5.01	6.72	17.37
7	233.5	2.54	4.67	5.52	12.73
8	229.5	4.35	4.35	5.01	13.71
9	239	5.02	5.02	4.36	14.4
10	218	5.5	4.81	1.94	12.25
11	231	6.06	3.24	3.47	12.77
12	223.5	6.71	4.69	1.56	12.96
13	231.5	4.75	5.61	4.53	14.89
14	231.5	4.32	3.89	4.53	12.74
15	226.5	4.63	6.18	3.35	14.16
16	226.5	7.5	5.51	4.63	17.64
17	232.5	2.8	4.25	4.51	11.56
18	228	5.04	5.26	3.5	13.80
19	227	2.86	4.62	4.18	11.66
20	223.5	4.8	5.59	4.47	14.87
21	222.5	7.19	4.94	4.04	16.17

Table XII. Length of field curing periods and results in storage.

1930

Days cured in field	Weight of onions (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
1	474.0	6.4	6.1	2.0	14.5
2	241.5	10.7	6.2	2.8	19.7
3	242.0	11.3	5.9	2.2	19.4
4	239.5	10.2	6.0	2.7	18.9
5	240.5	9.7	5.6	3.1	18.4
6	237.0	10.5	4.8	3.5	18.8
7	235.5	11.2	4.4	6.7	22.3
8	240.5	13.0	5.4	2.7	21.1
9	239.5	15.0	6.6	2.7	24.3
10	502.0	13.7	5.4	1.9	21.0
11	228.0	12.7	5.2	2.6	20.5
12	243.5	13.1	4.9	1.4	19.4
13	226.0	12.5	5.7	2.4	20.6
14	239.5	14.6	5.0	3.1	22.7
15	238.5	11.9	5.0	2.7	19.6
16	238.5	15.7	5.8	2.3	23.8
17	234.5	12.5	5.9	2.3	20.7
18	237.5	13.2	5.0	2.7	20.9
19	237.5	15.3	5.8	1.8	22.9
20	237.5	12.4	5.4	4.0	21.8
21	480.0	7.3	7.7	3.2	18.2

Table XIII. Showing averaged results of field curing periods (1929 and 1930).

Days cured in field	Total losses in storage (Percentage)	Average losses (Percentage)
		1 to 5 days
1	18.41	
2	17.91	
3	14.64	
4	14.54	
5	16.84	
		16.67
6	18.08	(6 to 10 days)
7	17.51	
8	17.4	
9	19.35	
10	16.62	
		17.79
11	16.63	(11 to 15 days)
12	16.68	
13	17.74	
14	17.72	
15	16.88	
		17.13
16	20.72	(16 to 21 days)
17	16.13	
18	17.35	
19	17.28	
20	18.33	
21	17.18	
		17.83

windrow for four days, then topped and placed in crates to be cured in the field, and under a shed, for an additional ten days. After curing, the lots were placed in the same storage room. The bulbs were weighed when topped and again weighed at the end of the storage seasons. Rots and sprouts were graded out and weighed at the close of the season.

The figures in Table XIV show in both the dry and wet curing seasons of 1929 and 1930, respectively, that onions cured in the field kept better than those cured in an open shed. However, the differences are small. When considering the cost of providing curing sheds and the negative results secured here, there is no indication, at present, of the desirability of curing under shelter.

Long and short topped bulbs. This experiment was started in 1929 and was repeated in 1930. The onions were of the same variety and strain, were pulled the same day, cured in windrows four days, topped, field cured for ten days and then placed in the same storage room. Losses in storage were determined at the end of the storage season.

In 1929 the lots consisted of two crates each. In 1930 the lots consisted of five crates each. The data for this experiment are presented in Table XV.

The comparison of long, medium and short topped onions, as shown in Table XV, indicates that topping onions at the natural break in the neck, or "medium topped", is to be recommended. The short topped bulbs during the 1929

Table XIV. Curing under a shed as compared to curing in the field.

Year	Treatment	Weight of onions (lbs)	Losses in storage (Percentage)			
			Rot loss	Moisture loss	Sprout loss	Total loss
1929	Cured in shed	455	2.1	12.14	5.1	19.34
1929	Cured in field	451	2.88	9.97	4.1	16.95
1930	Cured in shed	482	9.2	7.05	2.5	18.75
1930	Cured in field	485	6.4	5.5	4.4	16.3
Average	Cured in shed					19.54
	Cured in field					16.62

Table XV. Comparison of keeping qualities of long and close topped onions.

Year	Treatment of bulbs	Weight of onions (lbs)	Losses in storage (Percentage)			
			Rot loss	Moisture loss	Sprout loss	Total loss
1929	Long topped (2½")	91.0	1.3	8.7	2.1	12.10
1929	Short topped (close to bulb)	90.5	0.0	7.7	8.28	15.98
1930	Long topped (3")	215.5	20.4	5.5	.92	26.82
1930	Medium topped (at natural break in neck)	230.5	14.3	5.3	2.3	21.9
1930	Short topped (close to bulb)	236.0	17.0	7.8	2.3	27.1

season showed greater sprout loss than did the medium topped onions. According to Jones (12) and Boswell (13) this is probably a result of greater availability of oxygen. During the 1930 season the increase in sprouted onions was not so marked, yet greater than was the case with those that were long topped. Rot losses were less with the short and medium topped bulbs.

Graded, field-run and cull onions in storage. This project was started in an effort to determine the advantages of grading onions before placing them in storage. The culls were doubles, splits and scallions. The results are given in Table XVI.

The comparison of graded, field-run and cull onions shows, primarily, that the largest amount of moisture is given off by the culls. This results in higher relative humidity of the air in the storage house and a more favorable environment for the development of rot organisms. This would indicate that grading onions before placing them in permanent storage would reduce losses in storage. High humidity in onion storehouses is more conducive to increases in rot losses. Data will be presented to support this statement.

Curing in the field with tops left on as compared to curing with tops removed. The onions used in this experiment were of the same variety and strain and were subjected to the same growing conditions. The onions were

Table XVI. Graded, field-run and cull* onions

Year	Grades of onions	Weight of onions (lbs)	Losses in storage (Percentage)			
			Rot Loss	Moisture loss	Sprout loss	Total loss
1929	Graded bulbs	454.	4.7	5.5	7.0	17.2
1929	Field-run	451.	5.2	4.8	10.0	20.0
1929	Culls	451.	11.7	8.6	38.6	58.9
1930	Graded bulbs	238.5	9.8	3.7	0.0	13.5
1930	Field-run	577.	12.9	3.6	3.3	19.8
1930	Culls	178.	8.1	7.3	19.3	34.7
Average	Graded bulbs		7.2	4.1	3.5	14.8
Average	Field-run		9.0	4.2	6.6	19.8
Average	Culls		9.9	7.9	28.9	46.7

*Scallions, doubles and splits.

pulled and allowed to cure on the ground. Ten crate lots of these onions were topped 1, 5, 10 and 15 days after pulling. After topping, the bulbs were left in the crates in the field until the fifteenth day when all lots were placed in storage. The onions were weighed when placed in storage and losses were determined at the close of the season. The bulbs were kept in the same storage room. Results of this project are given in Table XVII.

Curing onions with tops left on gave very good results, as is shown in the preceding table. It is suggested that a large part of the infection in bulbs may occur at the time of topping. It is often the case under conditions in the Arkansas Valley to find onions being pulled before the tops have dried out and fallen over. The customary two or three days of curing in the windrow before topping does not allow the tops to completely dry out. Therefore, when topped, the necks of the onions are still succulent and the surface of the cut is damp from exuding plant juice. This freshly cut surface will provide a favorable means of entrance for disease organisms. Contamination may come from the clipping shears, which may have been used on diseased bulbs, or spores of the rot organisms may be carried by air currents and light on the cut surfaces of the bulb necks. On the other hand, when the bulbs are cured for ten or fifteen days before topping, the necks will have become thoroughly desiccated. Topping at this time exposes no succulent tissue and it may be reason-

Table XVII. Topping onions 1, 5, 10 and 15 days after pulling.

1930

Treatment	Weight of onions (lbs)	Losses in storage (Percentage)			
		Rot loss	Moisture loss	Sprout loss	Total loss
Topped 1 day after pulling	477	15.19	5.03	2.6	22.82
Topped 5 days after pulling	492	15.3	9.3	2.1	26.7
Topped 10 days after pulling	473	10.2	1.2	1.79	13.19
Topped 15 days after pulling	453	6.09	4.4	1.8	12.29

ably be considered that chances for rot infection would thereby be greatly reduced, with resulting smaller rot losses in storage.

The results of this investigation generally agree with results secured by Walker (21). He found that with untopped bulbs (when sprayed with a spore suspension of the neck-rot fungus, Botrytis allii) infection was much less than with those which had been topped. He similarly found that untopped bulbs kept much better in storage than topped bulbs. He also reported that neck-rot can be controlled by artificial curing of the bulbs. Artificial curing results in thorough and rapid drying of neck tissue and produces conditions unfavorable to the development of the disease. Thorough drying out of the tops in the field before topping may serve the same purpose.

Influence of Conditions in Storage on the Keeping Qualities of Onions

Effect of bottom ventilation. In this project 25 crate lots of onions of the same variety and strain and subjected to the same harvesting and curing methods were stored in each compartment of the onion storage house. One compartment was provided with added ventilation through ventilators placed on the foundation. The other compartment was provided with doors and windows, only, for ventilation. Equal quantities of onions were stored in each compartment and the compartments were filled to 75

percent capacity. This resulted in comparable conditions for each room except for the ventilation. Temperature and relative humidity records were taken by means of hydrothermographs. The average temperature and relative humidity record for the season was determined by taking the maximum and minimum readings for each day, averaging them and then averaging the daily records for the season. The houses were opened for ventilation early in the mornings. Heat was provided, when necessary, by means of a coal burning stove in each compartment. Results are shown in Table XVIII.

Humidity and temperature records during the 1929 season show that practically the same conditions of humidity and temperature obtained for each compartment. The loss in storage for the onions in the check compartment was slightly less than for the onions in the compartment provided with bottom ventilation. It would therefore appear that, in the ordinary small storage house, sufficient ventilation is provided by means of doors and windows.

Effect of high relative humidity. The same project described above was started in the fall of 1930. However, during the snowstorm of November 19 and 20 large quantities of snow were blown into the north compartment of the storage house. As it was impossible to thoroughly dry out this section of the house, the project was changed to a study of high relative humidity in storage, lower relative

Table XVIII. Comparison of bottom ventilation and humidity and temperature records in storage.

1929

Method of ventilation	Weight of onions (lbs)	Losses in storage per-centage	Average relative humidity per-centage	Average temperature degrees Fahrenheit
Bottom ventilation	1,158.5	17.04	56.97	40.28
Ventilation with doors and windows only	1,157	15.73	56.35	39.53

Table XIX. Effect of high relative humidity in storage.

1930

Condition in storage	Weight of onions (lbs)	Rot Losses in storage per-centage	Average relative humidity centage	Average temperature t degrees Fahrenheit
High humidity	1,059	19.0	73.7	40.6
Low humidity	1,064	14.4	47.7	41.5

humidity and the effect on stored onions. Twenty crate lots of onions of the same variety and strain, subjected to the same harvesting and curing processes, were used in this work.

The records, given in Table XIX, show a greatly increased relative humidity in the north compartment as compared to the south compartment. Temperature records were approximately the same in each section. The quite considerable increase in rot loss of the onions in the north compartment undoubtedly must have resulted from the increased moisture content of the air and its influence in creating a favorable environment for the development of rot organisms.

SUMMARY

The investigations reported in this paper cover one and two years' results. In order to reduce variations caused by weather conditions during harvesting, curing and storage periods, the work should be repeated over a number of years. Final conclusions cannot be drawn or recommendations given without further verification of the results. Where the various treatments show significant differences, the information may in time be used in planning practical demonstrations for onion growers. In addition to the practical value of the results, the direction for further work has been pointed out. By concentration of future work on the outstanding phases of the investigations, more rapid

progress can be made on the practical solution of storage problems.

Variety and strain trials showed that the varieties producing dark colored bulbs keep better, and that it is possible by breeding and selection to greatly improve a variety in regard to its keeping qualities. The 1930 trials of Sweet Spanish strains showed a difference in total storage losses of 14.2 percent between the best and poorest keeping strains. The variety trials resulted in even greater differences. An average of the storage losses for two years gives a difference of 25.24 percent between the Australian Brown and the Denia varieties, the best and the poorest keeping varieties in storage, respectively.

Cultural methods must be considered as factors in reducing losses in storage. Transplanted and field-sown onions seem to keep equally well. Little difference was found between early and late maturing bulbs. But immature bulbs showed less rot in storage, although sprout and moisture loss was greater. By better curing methods it should be possible to dry out immature bulbs so that sprouting will be greatly reduced. In this case, it may be that late planting of onions will prove of practical value in preventing rot losses in storage.

Applications of fertilizers, in most cases, resulted in greater storage losses. However, the addition of superphosphate, alone, resulted in a slight reduction in storage losses as compared to onions which did not receive fertil-

izer applications. Should this result be verified in future trials, two purposes may be served by application of this information: First, reduction in storage losses will result, and second, addition of the one plant food (phosphates) which is generally considered as low in Colorado soils, should be encouraged and better soil fertility will be maintained.

Late irrigation did not increase losses in storage. There was a difference of 4.6 percent loss in favor of onions irrigated one week before as compared to onions irrigated two weeks before pulling. If this treatment proves consistent in reducing rot loss and does not increase the susceptibility of the plant to disease, it should be of value in maintaining the growing period several days longer. This should result in increased yields.

The condition of the tops of the onions when removed was shown to be an important factor in affecting the amount of rot loss in storage. Curing onions for 10 and 15 days before topping resulted in approximately 5 and 10 percent reductions in rot loss as compared to onions which were topped one or five days after pulling. This treatment allows the neck to completely dry out before topping and, consequently, no succulent tissue is exposed to facilitate germination and spore development of the different rot organisms.

The results secured on this phase of the work are of the greatest practical value. The procedure can be

worked into the grower's method of caring for onions during the curing season, without necessitating added expense or trouble. However, it may be necessary to develop earlier maturing strains of the sweet Spanish onion, in order to hasten harvesting and give plenty of time for the curing process to be completed before severe frosts.

Topping onions at the natural "break" in the neck, instead of close topping or leaving three inches of the top attached to the bulb, seems to be advisable.

Curing onions under a shed as compared to curing them in the field did not decrease storage losses. A two year average of the results secured shows that onions cured in the field kept in storage with 2.92 percent less loss than the onions cured under sheds.

These results are in direct contrast to recommendations given to growers in eastern districts where it is necessary that curing be done under sheds. Dissemination of this information to the growers should prevent unnecessary expense proposed by some who are planning on building curing sheds.

Where onions were topped two or three days after pulling, curing periods of one to 21 days, in the field, did not show significant differences in the amount of storage losses. No direct correlation was found between length of field curing and losses in storage, when the onion tops were removed shortly after pulling.

The use of bottom ventilators in the Station stor-

age house did not lower temperature records or decrease the humidity content of the air, and had no effect on storage losses.

Increased humidity content of the air in the storage house resulted in greatly increased storage losses. Onions stored in the north compartment of the house, where an average relative humidity of 73.7 percent was maintained, showed a loss in rots of 19.0 percent, as compared to a loss of 14.4 percent for onions stored in the dry south compartment. In the south compartment, the average relative humidity was 47.7 percent. Temperature records were approximately the same in both compartments. This emphasizes the importance of keeping storage houses as dry as is possible.

Should the results of these investigations prove consistent in future trials, storage losses should be reduced to a minimum by the following practises and treatments; (1) late planting of onions, (2) late irrigations, (3) application of super-phosphate fertilizer, (4) curing 10 or 15 days in the field after pulling and before topping, (5) maintaining dry conditions in storage, and (6) selection and breeding for a better keeping strain of onions.

CONCLUSIONS

1. Dark yellow or brown colored bulbs keep better in storage than do the straw colored types.

2. Strains of the Sweet Spanish variety of onions vary in the percent of storage losses, showing the value of selection and breeding in reducing such losses.

3. There is no significant differences in the keeping qualities of transplanted and field-sown Sweet Spanish onions as grown in the Arkansas River Valley.

4. Date of planting trials indicate that immature onions are more resistant to storage rots than mature onions, but produce larger numbers of sprouted bulbs and lose more moisture.

5. The preliminary results of fertilizer treatments indicate that the addition of super-phosphate, alone, to onions reduces storage losses when compared to onions grown on check or untreated plots.

6. Late irrigation of onions, apparently, does not increase rot losses in storage.

7. When onions are topped within two or three days after pulling, the length of time they are cured in the field has little effect on storage losses.

8. Under conditions of the experiments, no advantage is gained by curing onions under an open shed as compared to curing in the field.

9. Onions topped at the natural "break" in the

neck keep better than those which are clipped close to the bulb or those left with three inches of the top attached.

10. Cull onions, such as doubles, splits and scallions, give off larger amounts of moisture than do graded bulbs.

11. Better storage conditions are insured by the removal of culls and undesirable bulbs, before the crop is placed in permanent storage.

12. Curing onions in the field until the tops are completely dried out, before topping, results in large reductions in rot losses, when compared to onions which are topped while the neck is still succulent.

13. Additional aeration by means of bottom ventilation does not seem to be necessary in the Station storage house.

14. Increased humidity in the storage house results in greatly increased rot losses.

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Plate I. Showing onions in the field near to maturity.

Plate II. Showing onions matured and tops fallen over.

Plate III. Showing onions pulled and piled in windrows.

Plate IV. Showing onions curing in windrow before being topped and placed in crates.

Phate V. Showing onions being topped and placed in crates for further curing in the field.

Plate VI. Portion of onion field showing damage caused by purple blotch infestation.

Plate VII. Double onion showing point of rot infection at base of bulb.

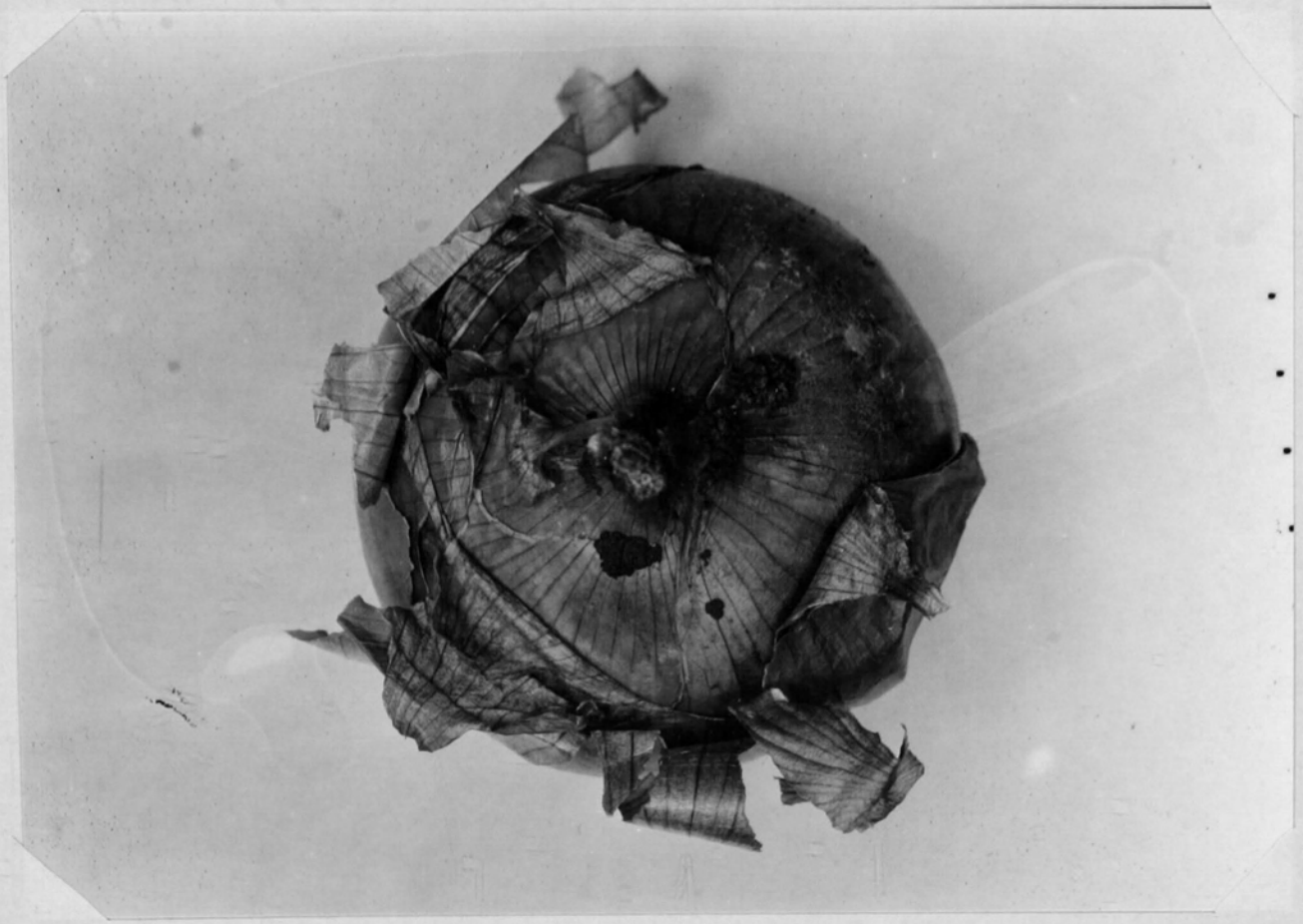

Plate VIII. Showing sclerotia formed by the Botrytis neck-rot organism.

Plate IX. Showing various stages in the development of neck-rot disease in the bulbs.