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A Study of Problems Relating to Production of Fall-Crop Irish Potatoes in Oklahoma

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INTRODUCTION

The large acreage of Irish potatoes grown each year in Oklahoma is planted as a spring crop which is harvested in June or early July. Because it is difficult to keep potatoes at this season without refrigerated storage, the spring crop provides but a temporary supply for local consumption. As a result, potatoes are brought into the State from the north during the fall and winter months and from the more southern states during late winter and early spring.

Because of this situation, many potato growers and gardeners plant a late or fall crop. Several different methods are used in starting this fall crop, but a common procedure is to plant back the small tubers graded out of the spring crop harvest. This planting is made shortly after the spring crop comes out, and frequently in the same field. This practice is convenient and economical as regards getting the crop seeded, but appears to be undesirable in other respects. The tubers are deeply dormant at this time and therefore remain in the soil a long time before sprouting. At times the moisture supply in the soil is largely depleted by the first crop and lack of moisture therefore limits the development of a second.

Several factors appear to be responsible for the widely varying results noted in fall potato crops. Low yields are frequently the result of poor stands of plants. In some years, unusually early frosts terminate the growing season before the tubers are large enough to make a profitable yield. Occasionally the moisture supply is a limiting factor, especially in the central and western parts of the State.

Decay of the seed pieces is found to be the principal cause of poor plant stands, and this decay has been found to be associated with high soil temperatures. Decay of seed planted for fall crops has generally been assumed to be pathological in nature, as is true for spring-planted seed; and this has led to the general assumption that whole tubers are preferable to cut sets as seed for the fall crop.

In the study here reported, the problem of seed piece decay was recognized to be of major importance, and an attempt was made to ascertain the fundamental cause.

REVIEW OF LITERATURE

Temperature of Germination Medium

Failure of Irish potatoes to germinate at high temperatures, accompanied by disintegration of the seed pieces, was described by Rosa (7) as relating to summer plantings of potatoes in California and, believing that the "decay" was due to soil organisms, assumed that whole tubers or suberized sets would be best for planting in fall crop production. However,

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in experiments conducted in 1925 he found that freshly cut sets and those cut in advance and stored at low temperatures (1° and 7° C.), where suberization progressed slowly if at all, gave the best plant stands in field plantings and emerged more rapidly than those more thoroughly suberized at higher temperatures of 12° to 22° C. In discussing these tests, he expressed the opinion that either (a) the cut sets, when placed at the higher temperatures, developed a secondary dormancy which delayed sprouting, or that (b) the new periderm interfered with gas exchange and thus retarded sprouting yet did not protect the sets from decay when planted in the soil. He also stated that "those factors which favor early sprouting of the sets are also favorable to a high percent germination or a good plant stand in the field," a point which is clearly indicated by his data.

In another report, Rosa (8) shows that small tubers treated with ethylene chlorhydrin and planted whole sprouted about 10 days earlier then untreated ones but required more time to get sprouts up than cut sets from untreated tubers and required twice as long to "get up" as did cut sets from treated tubers.

More recent data published by Thornton (13) places a new and entirely different interpretation on the relationship between gaseous exchange and sprouting in potato tubers and sets. This report indicates that sprouting is favored by the thickening of the periderm and other conditions which tend to limit the entrance of oxygen into the tubers. His data indicate that sprouting is possible after the periderm thickens to the point that the oxygen supply is reduced to a certain minimum quantity. The reason that cutting the tubers into sets hastens sprouting was the interpreted to be because the new periderm which is soon formed on the cut surface is less permeable to gases than the original covering of the tubers.

The respiratory behavior of tubers at high temperatures was studied by Ward (15), who found that at temperatures of 90° to 95° F. tubers which had been treated with ethylene chlorhydrin respired at a very high rate and that this rate was sustained over a period of about 12 days and until the tubers completely broke down.

That poor germination may be expected from blackhearted tubers has been shown by Stewart and Mix (11).

Smith (9) has shown that treatment with ethylene chlorhydrin increases the permeability of the periderms, favoring moisture loss as well as gaseous exchange.

Maturity of Tubers

A tendency for immature tubers to be slow in sprouting was reported by Rosa (7) after a three-year study, with the greatest difference occuring in a 1926 planting of Idaho Rurals when immature tubers harvested May 20 emerged 18 days later in a fall planting than did mature ones which were harvested June 29. Werner (18) made similar observations by sprouting cut sets of fall harvested Triumph tubers in the greenhouse. Immature tubers were harvested from May 10 planting on August 2 and mature ones on October 2. His results indicate that the immature tubers from the late planting sprouted more slowly than mature ones harvested on the same date (October 2), while tubers immature because of early harvesting (August 2) sprouted more promptly than those harvested when mature on October 2. This was true both for seed treated with ethylene chlorlydrin and for that planted untreated. From his results, Werner concluded that the tubers which were harvested early after-ripened faster in storage (38-40° F.) than did those left to mature on the vines.

Storage Temperature

The work of Muller-Thurgau published at an early date (1882) is widely cited as indicating that low storage temperatures abbreviate the dormant period in potato tubers. This work indicated that tubers stored at 0° C. for 40 days sprouted more promptly when planted at 20° C. than did tubers stored for the same period at 20° C. Newton (6) later published results indicating that immature tubers stored at 5° C. sprouted (when planted) more readily than those stored at 20° C. Stuart (12) expressed the same opinion regarding the effect of low storage temperatures on the rest period in potato tubers.

Rosa's studies showed somewhat different results in that temperatures of 1-8° C. served to delay sprouting as compared to storage temperatures of 23°. Similarly, temperatures of 28 to 30° C. induce earlier sprouting, in most cases, than was secured from tubers stored at 23°. Rosa's work also indicated that moist storage (tubers packed in wet sawdust) at an intermediate temperature (22°) favored rapid sprouting and better stands of plants in field planting of fall crop potatoes. Werner (18) compared cellar storage (45° F.) for dormant Triumph tubers with cold storage at temperatures below 45° and found that sprouting was generally more rapid for tubers stored at the higher temperature. Similar results were secured by Smith (10) in studying the winter storage of seed used in spring plantings. Tubers stored at 32-35° F. generally sprouted more slowly than those stored at temperatures of 40-50°. In seasons when early sprouting was favorable to larger yields the higher storage temperatures were best.

Use of Straw Mulch

Use of straw mulch in spring crop potato production in Oklahoma was investigated at a relatively early date by Waugh (16) and later by Morris (5) with favorable results. More recently results relating to this practice have been published by Werner (17) in Nebraska and by Bushwell (1) in Ohio. The benefits secured in favor of the use of the straw mulch on potatoes were found to be related to a lower soil temperature and to the conservation of moisture. Thus, the value of the mulch is determined by seasonal factors such as rainfall and prevailing temperatures.

MATERIALS AND METHODS

Certain methods or procedures which were used throughout this investigation are described here. Variations from these procedures occurred at times, and these deviations are given in later discussions.

Tubers from the spring crop were used extensively in making the fall crop plantings and an effort was made to hold the size of sets constant. The fall crop seed was selected from the No. 2 tubers in the spring crop, with those weighing about 2 ounces each being saved for the preparation of cut sets. These tubers were cut into halves longitudinally to provide one-ounce sets which were planted immediately after cutting in an unsuberized condition. Other tubers weighing about one ounce each were saved for planting as whole tubers.

After the seed tubers were selected, they were placed in storage in bags or baskets until planting time. Two storage environments were used, that found in an underground root cellar where the temperature was about 76° to 80° F. and the humidity was fairly high, and that found in a refrigerated storage where the temperature averaged about 50° F. with a fairly moist atmosphere. The tubers in the cellar storage were left there until planting time, while those in refrigerated storage were moved to the cellar a few days in advance of planting.

A standard ethylene chlorhydrin treatment was used most extensively throughout the investigations. It consisted of a 24-hour vapor exposure using 0.5 cc of the 40% commercial preparation per liter capacity of the container. This concentration and this treatment period were selected as being sufficient to induce early sprouting in the tubers and not so likely to induce seed piece decay as may result when greater concentrations or longer treatment periods are used. Forty-liter cans were used for treating most of the tubers and these were filled about two-thirds full as a maximum load. Twenty cubic centimeters of the ethylene chlorhydrin preparation were applied to cheese cloth covering a mesh wire cylinder or cone which was then set on a shalow dish which in turn was placed on the tubers. The can was tightly closed for the 24-hour period after which the tubers were removed to wire baskets or other open containers and exposed to free air circulation for some time before planting. These treatments were applied to the whole tubers and were usually carried out in the storage cellar, although in two instances larger lots of tubers were treated in a 3′x3′x7′ chamber in which the temperature was maintained at 70° F.

Planting was accomplished in most of the field studies with an assist-feed planter on which the discs were set to cover the seed to a depth of about four inches with a low to moderate ridge. When a higher ridge was desired, additional soil was thrown up by means of a shovel plow immediately following planting. The planter was regulated to drop the sets at about 12-14″ intervals. This spacing was used to assure accuracy in making emergence counts in preference to a closer spacing which would be more favorable to production in a fall planting.

In most instances the various treatments being studied were planted in replicated plots, each plot being represented by a single row 65-70′ long. The plot rows were planted three feet apart and each was planted with 60 or 65 sets. The sets for each plot were counted out into small bags in advance so the several plots of a given row might be planted with only brief stops between the plots to set a stake and start a new lot of seed pieces. In this method each plot received the same number of seed pieces but plot lengths varied slightly since this was determined by the planter and not by direct measurement. Such variations were largely overcome in averaging the several plots for a given treatment. Some variations from this planting procedure will be noted later in the discussions for certain of the tests.

Because soil temperature was found to be an important factor in this study, an effort was made to secure continuous records representing that found in the soil at the level at which the seed pieces were planted. To this end one or more distance thermographs were used and these were set up at the time of planting with the capillary in the row along with the seed. The extension tubes and the instrument shelters were so arranged that the usual cultivation treatments were possible. The mean temperatures were determined on a daily basis by integrating the weekly charts with a planimeter.

Rainfall was measured by means of a standard gauge located on the farm and placed near some of the experimental plots.

The unirrigated plantings were, with one exception, made in fields which had received fallow treatment. The irrigated series were grown in plots following spring crops of tomatoes or snap beans.

In the field trials, sprout emergence counts were taken along with other data as an indication of the rate of sprouting. The 50% point was determined from the cumulative emergence curves and is expressed as the number of days from planting to 50% up. It is based on the total hills from which sprouts emerged and not on the total number of hills or the total number of sets planted.

INVESTIGATIONS CONDUCTED WITH CONTROLLED SOIL TEMPERATURES

Experimental Procedure and Results

Studies were started in 1937 in which potato sets and tubers were planted in soils with the temperatures maintained at levels which were far above the optimum and at which it was expected that normal germination and sprout emergence would not take place. In the first test, three hotbeds heated with electric cables were used, with the thermostats set to cut off at 68°, 83° and 93° F., respectively. The tubers were of the Triumph variety and had been harvested about two months at the time of planting. Emergence records were taken during the germinating period and the study was finally concluded with the removal and examination of the seed pieces. The results are partially summarized in Table I.* Of the three temperatures investigated, 68° was most favorable to germination while at 93° the sets all broke down without germinating.

Table I.—Germination and Decay of Potato Seed (Cut Sets) at Different Soil Temperatures; 1937.

	SOIL TEMPERATURE (F°)		
	68	83	83
Number sets planted	18	18	18
Percent germination	61.1	16.7	0.0
Percent decay	33.3	83.3	100.0

Planted April 26, 1937, as cut sets without ethylene chlorhydrin treatment and about two months after tubers were harvested.

Assuming that the reduced germination at high temperatures was the result of seed piece decay due to infections by rot-producing fungi, a second test was conducted with treatments designed to offer the same protection against these infections. In one series the sets were cut a week in advance of planting and kept moist at about 70° to allow the cut surfaces to become suberized. Other sets were cut at planting time and lots of both the suberized and freshly cut sets were treated with several chemicals (as dry powder) that were found by Clayton (3) and by Vincent and Pawson (15) to have disinfecting properties when used on seed potatoes. Some small tubers were also planted without being cut.

These prepared sets and tubers were planted in soil in two hotbeds with thermostat settings of 80° and 90° F. The test began on June 4, and before its completion the influence of outside temperatures caused the temperature of the one bed to exceed the 80° indicated.

The results of this test as summarized in Table II suggest that both the chemical and suberization treatments were ineffective in checking the rot of the sets at these high temperatures. In fact the best germination was secured when freshly cut and untreated sets were planted. Examina-

* Data presented in Tables I, II, and III secured by Louise P. Kenworthy (Unpublished Masters Degree Thesis, 1938).

tion of the seed pieces at the close of the trial period indicated that certain of the chemicals had preserved the exterior of the sets to some extent but that the internal tissues were entirely broken down.

These results suggested that the so-called decay of potato sets at high soil temperatures is not due directly to fungi or decay producing organisms. The breakdown appeared to be related to some internal condition and the response of whole tubers and suberized sets suggested some disorder similar to blackhearting as being the direct cause of the seed piece breakdown.

The effect of blackhearting on germination was observed in a later test. Dormant Triumph tubers were treated with ethylene chlorlydrin by the vapor method using 1 cc per liter volume of air. The treatment was followed by a 24-hour airing period after which the treated tubers along with untreated ones were stored at temperatures of 85°, 90° and 95° in constant-temperature chambers. Lots were removed at the end of 5, 12, and 21 days for germination tests. At the first interval, considerable blackhearting was noted when the tubers were cut for planting, especialy in those stored at 95°. The sets were therefore classified into groups according to the degree of blackhearting, before being planted. The germination tests were conducted in a peat-sand mixture contained in flats at a temperature of about 70° in the greenhouse.

As shown in Table III, the percentage of germination varied inversely with the degree of blackhearting and little or no germination resulted when the tubers were moderately or severely affected with blackheart. The tubers stored untreated showed little or no blackheart, and when planted they germinated 92.2, 97.3 and 100 percent following 95°, 90° and 85° storage, respectively. These results suggested that the combined stimulation from high temperatures and the chemical treatment was sufficient to raise the rate of respiration to a point that the oxygen supply was inadequate and blackhearting resulted. When a large part of the set was injured in this way it broke down without sprouting. It should also be noted that

Table II.—Germination of Suberized and Newly Cut Sets at Two Soil Temperatures in Relation to Certain Chemical Treatments.

	Soil temperature	Number of sets planted	Sprouted	Decayed unsprouted	Sound; unsprouted
			%	%	%
Suberized sets					
No chemical treatment	80°	42	7.1	73.8	19.1
Semesan	90	21	0.0	100.0	0.0
Sufur and lime	90	21	0.0	100.0	0.0
Zinc oxide	90	21	4.8	85.7	9.5
Copper carbonate	90	21	0.0	100.0	0.0
Red copper oxide	80	42	2.4	78.6	19.0
Newly cut sets					
No chemical treatment	90	42	69.1	11.9	19.0
Semesan	90	21	9.5	90.5	0.0
Sulfur and lime	90	21	14.3	81.0	4.7
Zinc oxide	90	21	14.3	76.2	9.5
Copper carbonate	90	21	23.8	76.2	0.0
Copper acetate and lime	90	21	42.9	57.1	0.0
Whole tubers untreated	80	42	0.0	69.1	30.9

Planted in hotbeds June 4, 1937, with 36 days allowed for germination. Chemicals were applied to the sets as a dry powder. Hydrated lime was added to sulfur and to copper acetate to make a 50-50 mixture by weight.

Table III.—Germination of Cuts Sets From Tubers Affected With Varying Degrees Of Blackhearting.

Storage temperature following treatment with ethylene chlorhydrin	DEGREE OF BLACKHEART INJURY:							
	None		Slight		Medium		Severe	
	No. sets planted	Percent sprouted	No. sets planted	Percent sprouted	No. sets planted	Percent sprouted	No. sets planted	Percent sprouted
95° F.	26	50.0	23	8.7	39	0.0	42	0.0
90° F.	88	80.2	27	25.9	22	4.6	22	0.0
80° F.	86	79.2	63	20.6	5	0.0	23	0.0
Average		76.0		19.5		1.2		0.0

Sets germinated in a peat-sand mixture in the greenhouse at a temperature of about 70° F.

the seed that was not given the chemical treatment germinated better than that which had been treated, even when the latter did not show blackheart injury.

Additional studies were conducted on storage and germination temperatures in 1938, using tubers of the Triumph variety harvested June 28 and stored in the cellar. Ethylene chlorhydrin treatment was applied to a part of the tubers using 0.5 cc per liter air space by the vapor method. On August 24, both treated and untreated tubers were placed in special 3'x3'x7' cabinets held at 70° and 95° F. Plantings were made at intervals of 4, 12, and 18 days into a peat-sand mixture in flats. Both newly cut sets and whole tubers were planted. As previously indicated, the sets were prepared by cutting 2-ounce tubers into halves. The germination tests were carried out in the same cabinets with the storage lots; i. e., tubers and sets from 70° storage were germinated at that temperature. A few days after the first lots were planted it was discovered that the sets planted at 95° were largely broken down, so the temperature of that cabinet was lowered to 90° for the remainder of the experimental period. At the time of the last planting (18 days), duplicate lots were planted, taking tubers from the 70° storage for germination tests at 90° and tubers from 90° to germinate at 70°. An interval of 22 to 24 days was required to complete the germination period of the sets and tubers in the several plantings made in this test, and emergence counts were taken at frequent intervals during this germination period.

The results of this study as summarized in Table IV indicate that temperatures as high as 95° F. cause the tubers and sets to break down without sprouting. At 90° little germination resulted when whole tubers were planted but a good part of the cut sets survived to produce sprouts at this temperatture. It is also evident that the germination improved for these cut sets in the later plantings.

Early sprouting of the seed pieces was favored by the cutting of the tubers, by ethylene chlorhydrin treatment, and by late plantings; and in general all these favored an increase in the percentage of germination or resulted in less decay. This correlation between the time required for the sprouts to emerge and the final percentage of germination was especially marked in the case of whole tubers (planted without cutting) where $r = -.708 \pm .097$.

Other observations relating to the response of tubers and sets at high soil temperatures were made in 1939 and 1940. The tubers used were harvested in the fall crop on November 7, 1939, being taken from cellar storage to a 70° cabinet on December 16. At this time the tubers were

Table IV.—Rate and Percentage of Sprouting for Potato Sets and Tubers in Relation to Storage Temperature, Soil Temperature, and Chemical Treatment.*

	TREATED WITH E. CHLORDYDRIN				NOT TREATED			
	Whole Tubers		Cut Sets		Whole Tubers		Cut Sets	
	70° F.	90° F.	70° F.	90° F.	70° F.	90° F.	70° F.	90° F.
Series I. (Planted after 4 days)								
Days to 50% emerged	13	---	9	---	15	---	10	---
Percent germination	45	0**	93	0**	23	0**	93	0**
Decayed-unsprouted, percent	55	100	2	100	65	100	0	100
Total weight sprouts (gms.)	78	---	208	---	52	---	199	---
Series II. Planted after 10 days)								
Days to 50% emerged	10	14	7	10	12	---	6	12
Percent germination	83	3	100	40	43	0	93	10
Decayed-unsprouted, percent	10	95	0	60	50	100	0	90
Total weight sprouts gms.)	156	1	215	157	49	---	163	14
Series III. (Planted after 18 days)								
Days to 50% emerged	9	13	9	14	14	---	9	12
Percent gerimination	100	3	95	78	65	0	100	53
Decayed-unsprouted, percent	0	97	0	22	30	100	0	47
Total weight sprouts (gms.)	189	4	200	351	218	---	313	193
Series IV. (Planted after 18 days, reversing temperature)								
Days to 50% emerged	18	12	13	11	---	12	13	10
Percent germination	8	93	93	100	3	40	90	98
Decayed-unsprouted, percent	65	5	2	0	85	57	7	2
Total weight sprouts (gms.)	5	94	187	150	2	94	121	395

* Tubers stored August 24, 1938, and then placed to germinate at the intervals and temperatures indicated, except in Series IV where tubers from 70° storage were germinated at 90° and tubers from 90° were germinated at 70° F. The arrangement of this series in the table is according to the temperatures at which germination took place. Each lot included 40 sets.

** Cabinet temperature was at 95° for this first series.

graded into two size groups, the larger (ave. wt. 0.123 lb.) to be cut in half before planting and smaller ones (ave. wt. 0.070 lb.) to be planted whole. Tubers of both sizes were treated with ethyelne chlorlydrin on December 22 and were later packed in moist excelsior to induce sprouting. After 20 days at 70° the sprouts averaged about 3/16 inch. At that time, some of the small tubers were grafted as follows: a cylinder of tissue cut longitudinally through a sprouted tuber was inserted into a hole made in an unsprouted tuber, while the cylinder of tissue taken from the unsprouted tuber was inserted into a sprouted tuber. Cork borers, numbers 7, 8, and 9, were employed to cut the cylinders. The grafts were made in such a way as to secure firm contact between the tissues of the tuber and cylinder to encourage the graft union. After grafting, the tubers were returned to the moist excelsior for five days before planting.

At the time these grafts were made, additional tubers were treated with ethylene chlorhydrin; and on January 25 all lots were planted in flats and placed in cabinets maintaind at temperatures of 70, 87, and 92° F. One series of sets had the cut surface sealed over with paraffin (softened by the addition of lanolin). The peat-sand germinated medium in the flats was kept moist and emergence records were taken throughout the germinating period. Since there was some variation in temperature at different shelves in the cabinets and because the large number of flats used required more space than was found on one shelf, the temperatures of the germinating media were secured with thermometers daily over a period of time and the means calculated as being representative of the temperatures to which the tubers and sets were exposed. These means are used in Tables V and VI, which summarize the results of this test.

As shown in Table V, the temperature of the moist germinating mediums was somewhat lower than that of the air temperature in the cabinets and the germination for most of the tubers and sets was relatively high. As a whole, the cut sets germinated earlier than the whole tubers and with a higher average percentage. Pre-sprouting seemed to favor emergence in the whole tubers and especially at the highest temperature (86-87° F.). Treating with ethylene chlorhydrin produced similar results.

Table VI shows the response of the cut sets in which the cut surface was paraffined. With these sets, temperatures of 87° and 90° F. caused a marked reduction in the germination and at 90° the greater part of the sets decayed without sprouting.

There was not a great deal of difference in the germination and emergence for the two kinds of grafted tubers. In general, the sprouted tubers with the unsprouted cylinder responded about the same as did the sprouted tubers as given in Table V. When the sprouted cylinder was grafted into an unsprouted tuber there was better germination and less decay at 81° and 86° than was secured for untreated tubers as indicated by the results given in Table V. Whether this difference is due to the presence of the sprout-bearing tissue or to the wound stimulus in cutting the tubers in grafting is not definitely indicated. A series of tubers with dormant buds on both the cylinder and tuber would have been helpful in making this point clear. In most cases the apical eyes included on the cylinders sprouted, but these sprouts were slender and looked much like these produced on the small plugs or cylinders which were planted ungrafted for observation on this point. Observations at the close of the experiment indicated that the graft union between cylinder and tuber was not extensive. However, it does appear likely that the presence of sprouts on tubers or sets at the time of planting at high soil temperatures is of some benefit as an aid to getting sprouts up and also in reducing the proportion of sets which decay.

Table V.—Germination of Potato Tubers and Cut Sets at Various Temperatures in Relation to Pre-Sprouting and Ethylene Chlorhydrin Treatments.

	PRE-SPROUTED			NOT TREATED			TREATED (E. C.)		
	68° F.	81° F.	86° F.	68° F.	84° F.	87° F.	67° F.	84° F.	87° F.
Planted as Whole Tubers									
Days to 50% emerged	13	10	12	20	24	25	19	22	23
Percent decayed (unsprouted)		3			10	37	23	3	7
Total weight of sprouts (gms.)	250	301	233	89	181	75	133	221	118
Average length of sprouts (inches	7.5	10.1	7.3	5.6	4.6	4.1	6.6	7.7	5.5
Percent germinated	100	97	100	100	80	50	77	90	93
Planted as Cut Sets									
Days to 50% emerged	14	15	14	16	16	17	14	10	17
Percent decayed (unsprouted)	---	---	---	---	---	13	---	---	3
Total weight of sprouts (gms.)	136	187	267	184	195	144	320	544	172
Average length of sprouts (inches)	7.8	8.6	7.9	7.1	7.9	4.4	7.2	13.9	6.0
Percent germinated	100	90	100	100	100	30	100	100	93

Seed from Triumph fall crop of 1939. Planted to germinate in a peat-sand mixture on January 25, 1940. Temperatures as given represent means for the peat-sand mixture as taken with thermometers. Data based on 30 sets for each treatment.

Table VI.—Germination of (1) Potato Sets With Cut Surfaces Sealed with Paraffin and (2) Grafted Whole Tubers.

	CUT SURFACE Sealed (Paraffin)			SPROUTED CYLINDER; Unsprouted Tuber			UNSPROUTED CYLINDER; Sprouted Tuber		
	68° F.	87° F.	90° F.	68° F.	81° F.	86° F.	68° F.	81° F.	86° F.
Days to 50% emerged	19	22	23	12	15	12	13	12	13
Percent germinated	100	60	7	100	93	76	100	97	90
Percent decayed (unsprouted)			90		4	10		3	7
Total weight sprouts (gms.)	110	119	12	97	127	165	290	382	313
Average length sprouts (inches)	6.2	6.8	4.0	5.5	6.0	7.1	6.9	8.6	5.9

Seed from Triumph fall crop of 1939. Planted to germinate in a peat-sand mixture January 25, 1940. See text for description of grafted tubers. Data secured on lots of 30 sets.

Discussion of Controlled Temperature Studies

Summarizing the results of this phase of the investigation, it appears that soil temperatures in the range of 87 to 95° F. cause a marked reduction in the sprouting and emergence of sprouts from potato tubers or sets. This failure to germinate at high temperatures is largely due to a disintegration of the seed pieces, as was described by Rosa (7).

The results of the present study suggest that seed piece breakdown at high temperatures is not originally of pathological origin and that it appears to be associated with some physiological disorder such as blackhearting which arises in association with a high respiratory rate and a deficiency of oxygen. Germination tests with tubers in which blackhearting was clearly evident showed a close relationship between this kind of injury and seed piece decay.

The fact that newly cut sets decayed less at high soil temperatures than suberized sets or whole tubers was taken as evidence to support this assumption that the cause of the breakdown of the seed is not initially pathological but is physiological in nature and arises in relation to a deficiency of oxygen. Recent work by Thornton (13) relative to the entrance of oxygen into potato tubers might be interpreted to be opposed to this conclusion, since he reported that the wound periderm formed on the cut surfaces of potato tubers becomes thicker and therefore less permeable to gases than the original periderm. Granting that this is true, it should be understood that some time is required for the new periderm to develop on the cut surface to the point that it is equivalent to the original periderm as a barrier to the entrance of oxygen. Under conditions favorable for wound cork formation, it is probable that 12 to 16 days would be required; and according to Thornton's anatomical observations the wound periderm is poorly developed at the end of 8 days.

Under the circumstances, it is believed that the cut surface as related to oxygen penetration to the interior is a significant protection against the breakdown or destruction of the potato sets at high soil temperatures. It is suggested that the critical period is immediately after the sets are planted and that some changes take place in the sets to adjust them to the high temperature. Although this protection may be but temporary, it is present during the first week or two following plantings and when the increased oxygen supply is needed most. According to results published by Kimbrough (4), it would be expected that there would be an initial rise in the rate of respiration immediately after the seed is planted at the high temperature followed by a gradual lowering of the rate. Furthermore, it should be noted that sprouting had occurred in many cases before sufficient time had passed for the cut surfaces to become fully corked over and it is believed that this sprouting is helpful in preventing seed piece break down at high temperatures. These conclusions appear to be confirmed by the results of the field investigations (See page 46).

As indicated by Rosa's work and as shown in these studies, those factors which hasten sprouting favor a high percentage of germination and high final stand of plants and more specifically are associated with less decay of the seed pieces. Cutting the tubers, treating the tubers with ethylene chlorlydrin, and planting pre-sprouted sets and tubers were factors studied which served to hasten the emergence of sprouts and which in turn served to decrease the seed piece decay or to increase the emergence of sprouts.

Just why the sprouted tubers are less subject to the breakdown at high temperatures is not clearly indicated by the grafting tests, and further work should be done on this particular problem. Under field conditions, it is probable that pre-sprouting would be helpful even when the mother tuber or set is attacked by decay, in that early emergence of the sprouts increases the probability of the new plant becoming established before the food supply is cut off by decay.

FIELD STUDIES*

Experimental Procedure and Results

TIME OF HARVEST AND TIME OF PLANTING

1938

Harvests were made in a uniform field of spring-planted Triumph potatoes on June 15 and repeated again on June 20 and 27 and July 2 and 14. The tubers were quite immature for the first harvest and increased in maturity up to July 2, when the vines were mostly dying and the periderms were setting up on the tubers. The tubers left in the field for the final harvest were exposed to excessively high soil temperatures in the period July 3 to 7 and again July 11 to 14, and as a result some were injured by heating and decayed in the field or soon after harvesting. Only those tubers which appeared sound were selected from this lot for planting in the test plots.

The tubers of all harvests were kept in cellar storage until they were planted. Plantings were made in fallow ground on July 2 and 14 and August 3, using both whole and cut tubers. On August 3 a duplicate planting was made using seed treated with ethylene chlorhydrin. It should be noted that in the first two seedings some of the tubers were planted back the same day they were harvested.

Rainfall and soil temperature data as relating to these and other plantings made in 1938 are given in Figure 1. Sprout emergence counts were started on August 15 with the cut seed planted July 2. The sprout emergence progressed normally at first but by August 23 it was at a standstill and in some cases the count was actually diminished. At this time the daily soil temperatures were extremely high and remained so for about two weeks. Examination of some of the hills indicated that the sprout terminals were severely injured as they approached the surface of the soil (See Figure 2). When lower soil temperatures associated with rainfall came September 2 to 5, sprout emergence was resumed and fairly rapid emergence resulted for both whole and cut seed at this time. The behavior of some of lots of seed as regards sprout emergence is illustrated in Figure 3 and the final data are summarized in Table VII. Because of an early frost, the yield data were of little significance and are not included.

As was shown, the emergence trends were distorted because of heat injury to the sprouts before they emerged and thus the time required to reach the 50% point was unusually long for the early plantings. However, it is evident that the cut sets sprouted earlier than whole tubers (except for some lots in the first planting) and the time required for the sprouts to emerge decreased as the time of planting was delayed. There is also some tendency for the more mature tubers (harvested late) to send up sprouts earlier than the less mature tubers harvested June 15 and 20, although there are several exceptions to this. Such response is to be expected in the light of results published by Rosa (7)

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* For field studies conducted prior to 1938, see the following *Biennial Reports* of the Oklahoma Agricultural Experiment Station: 1936-38, pp. 113-4; 1934-36, pp. 55-6; 1932-34, pp. 231-4; 1930-32, pp. 235-6; and 1926-30, pp. 228-9.

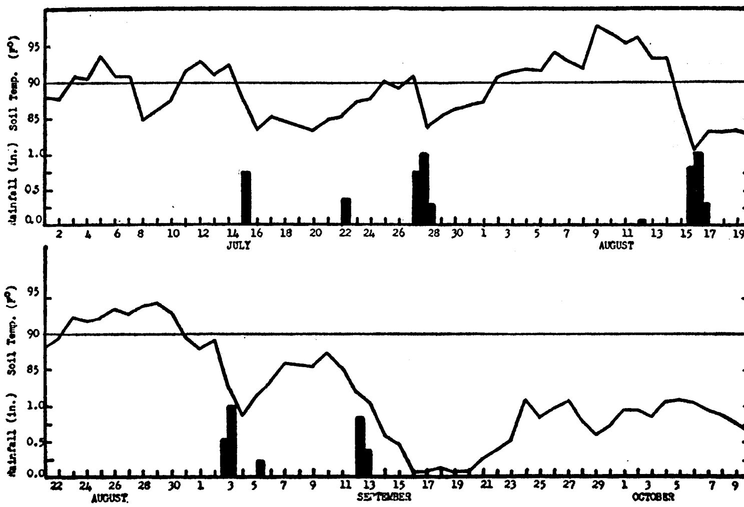

Figure 1.—Daily mean soil temperatures and rainfall data as relating to the fall potato plantings for the 1938 season. The temperatures were taken in the row at seed depth. Note the moderating influence of rainfall on the soil temperature.

The stand of plants for the August 3 planting was best and it appears that this was favored by more prompt sprouting of the sets while the seed planted at this time was also favored most by lower soil temperatures and rainfall beginning on August 15. The lowest stands of plants were secured in the July 14 planting.

The percentage of emergence or stand for the August 3 planting is presented graphically in Figure 4, where it is shown that (except for tubers harvested June 1) those treated with ethylene chlorhydrin and cut into sets before planting germinated best and that for this kind of seed the tubers harvested July 2 (planted 32 days following harvest) produced a maximum stand of 90%. When cut sets were planted without chemical treatment, a lower average stand resulted and a slight upward trend was found with the "age" of the seed. Relatively low stands resulted when whole tubers were planted with untreated seed, showing some increase in favor of the older seed (from the earlier harvests); while the treated tubers showed the reverse trend.

1939

For the time-of-planting test conducted in 1939, the seed tubers were removed from refrigerated storage a few days in advance of planting. The four "kinds" of seed were planted in a 4x4 Latin square on each planting date with 65 sets per plot. The entire series of five plantings composed a total of 20 adjacent rows about 280 feet long with four plots in each row. As in 1938, plantings were made in soil which had been given fallow treatment prior to planting the fall potato crop.

Figure 5 shows that heavy showers during the first week in July provided ample moisture for the first planting of this series. After this time, however, rainfall was limited for a time to light showers which served to

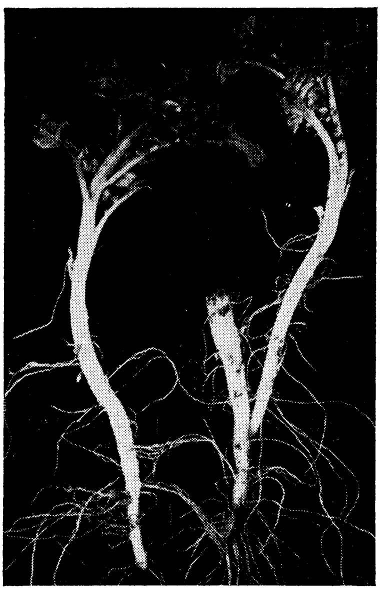

Figure 2.—High soil temperatures are injurious to sprout terminals. The picture at the left illustrates a sprout which was injured in the field, after which it produced laterals which successfully emerged to establish the plant. The lower picture shows sprout injury produced when the tubers were planted at a controlled temperature of 95°.

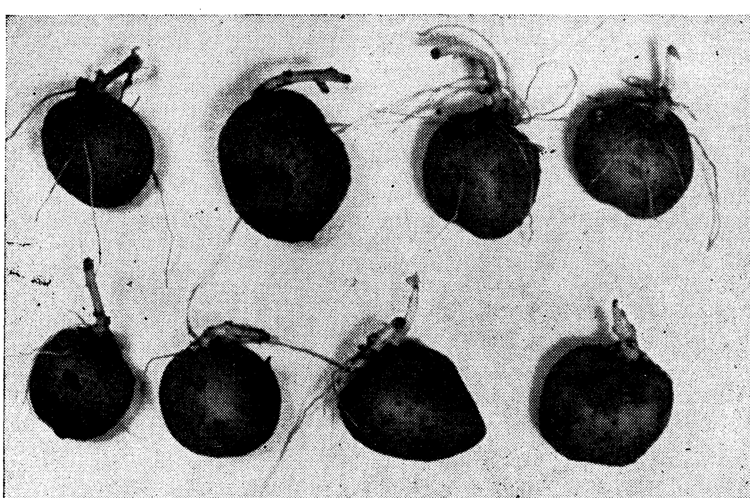

Table VII.—Rate of Sprout Emergence and Final Stand of Plants for Potato Seed in Relation to Tuber Maturity, Time of Planting, and Chemical Treatment; 1938.

Date of Harvest	TUBERS PLANTED WHOLE				PLANTED AS CUT SETS			
	Seed Untreated			Treated;	Seed Untreated			Treated;
	July 2	July 14	Aug. 3	Aug. 3	July 2	July 14	Aug. 3	Aug. 3
Days to 50% emerged								
June 15	73	65	68	*	74	60	45	37
June 20	74	67	62	*	74	62	43	39
June 27	75	61	*	*	76	55	39	40
July 2	73	61						
July 14	--	59	*	59	--	64	40	40
Percent emerged								
June 15	27	21	31	0	37	33	54	14
June 20	17	14	11	2	32	33	45	59
June 27	50	7	5	4	29	14	54	80
July 2	45	9	2	13	33	28	46	90
July 14	--	38	1	19	--	26	41	76

Tubers of Triumph variety stored in the cellar following harvest and until planted. Some seed treated with ethylene chlorhydrin prior to planting on August 3, 1938.

* Stands were too low to establish trend for emergence.

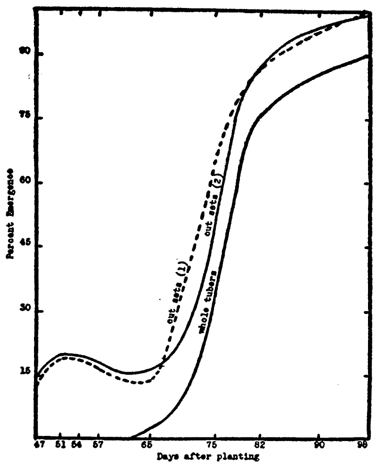

Figure 3. — Curves showing the emergence of sprouts for cut sets and whole tubers planted July 2, 1938. Note the emergence began first with cuts sets but these trends were distorted by heat injury to the sprout terminals (See Fig. 2) and as a result the trends for cut sets were not much different from that for whole tubers during the latter part of the emergence period.

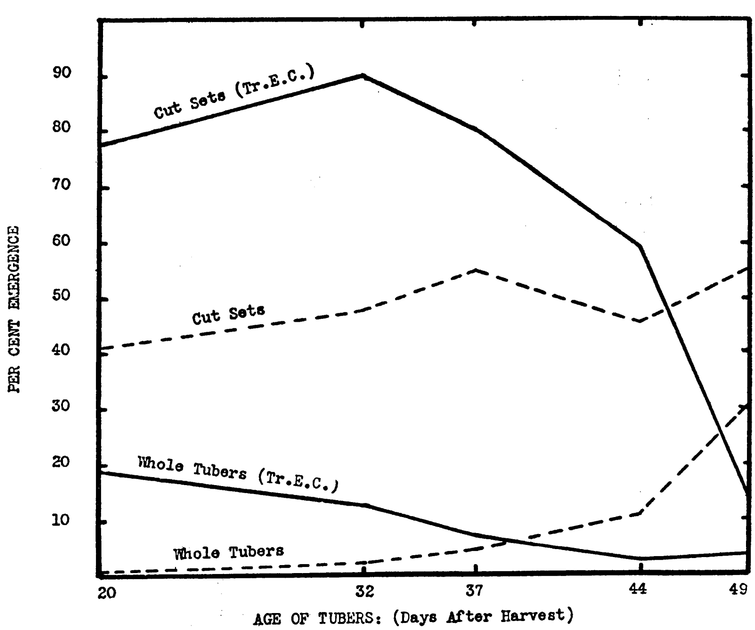

Figure 4.—Illustrating emergence or plant stand data for the four kinds of seed planted in the field on August 3, 1938. The 20-day seed was harvested July 14, the 49-day seed on June 15.

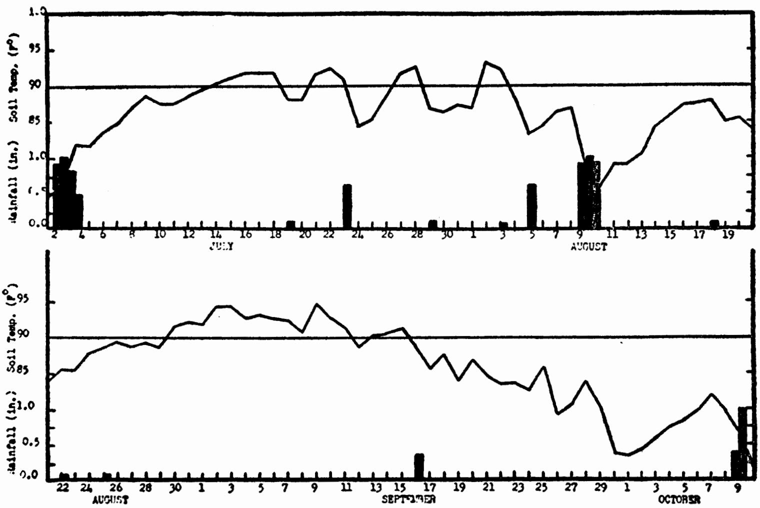

Figure 5.—Daily mean soil temperatures and rainfall data relating to the potato plantings made during the 1939 season.

lower the soil temperature temporarily but probably did not add to the effective soil moisture. Later showers (August 4 to 10) were more abundant, but they were the last for the growing season of 1939.

The rate of emergence and the final stand (percentage emerged) for this 1939 series are given in Table VIII, and the analysis of the data in Table IX. Data for final stand are given graphically in Figure 6. Because of the protracted dry period following the showers on August 10, the yield of tubers from this time of planting series was low and has been omitted as being of little significance.

1940

A time of harvest or "age of seed" study was made in 1940 with the Warba variety, in which five harvests were made in the spring crop, beginning June 15 when the tubers were relatively immature and ending with a harvest on July 6 when the condition of the vines indicated that full maturity was attained. At each harvest, seed for fall planting was selected to include two-ounce tubers for preparing cut sets and one-ounce tubers for planting as uncut sets and all were placed in cellar storage.

The ethylene chlorhydrin treatment was applied to a part of the seed tubers on July 22 and the field planting was made in fallow land four days later. The plantings were made in 5x5 squares with seed from the five harvests in each square. Four squares or series were planted as follows: (1) Whole tubers; (2) whole tubers treated with ethylene chlorhydrin; (3) cut sets; and (4) cut sets from treated tubers.

As indicated by Figure 7, the temperature and rainfall were quite agreeable for fall crop production, although there was some shortage of moisture during the latter part of the growing season. A late fall permitted the plants from cut seed (which emerged first) to come to full maturity before freezing temperatures arrived. The vines in the plantings where whole seed was used were still green when they were frozen on November 9. (See Fig. 8).

Table VIII.—Rate of Sprouting and Plant Stands in Relation to Time of Planting and Kinds of Seed; 1939.

Date of planting	WHOLE TUBERS		CUT SETS	
	Not treated	Treated (E. C.)	Not treated	Treated (E. C.)
Days to 50% emerged				
July 8	81	56	54	45
July 15	72	74	71	47
July 22	71	71	67	36
July 29	62	68	59	55
August 5	53	53	52	47
Percent emerged*				
July 8	10	8	28	35
July 15	9	10	11	2
July 22	11	9	43	45
July 29	17	15	38	63
August 5	5	3	47	26

Seed tubers of Triumph harvested June 21, 1939 and stored in refrigerator at about 50°. Some tubers were treated with ethylene chlorhydrin prior to planting in the field.

* Significant differences are found in each planting between whole and cut seed and between treated and untreated cut seed for the last two plantings.

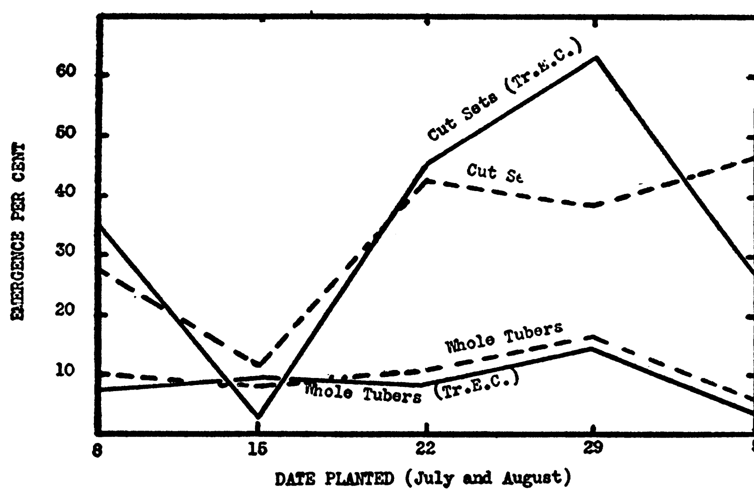

Figure 6.—Showing the percent emerged or plant stands for four kinds of seed in the time of planting series for 1939. See Figure 5 for weather data relating to these plantings.

Table IX.—Analysis of Variance for Plant Stand Data for 1939 Time of Planting Tests as Given in Table VIII.

Sourse of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	79	31,566.48		
Between blacks	3	1,604.84	534.95	5.87
Between rows	3	1,231.74	410.58	4.51
Between kinds of seed	3	1,774.24	591.41	* 6.49
Between planting dates	4	5,564.93	1,391.23	*15.28
Pl. dates × kinds of seed	12	16,473.08	1,029.57	*11.31
Remainder (error)	54	4,917.65	91.07	

* Exceeds the 1% point.

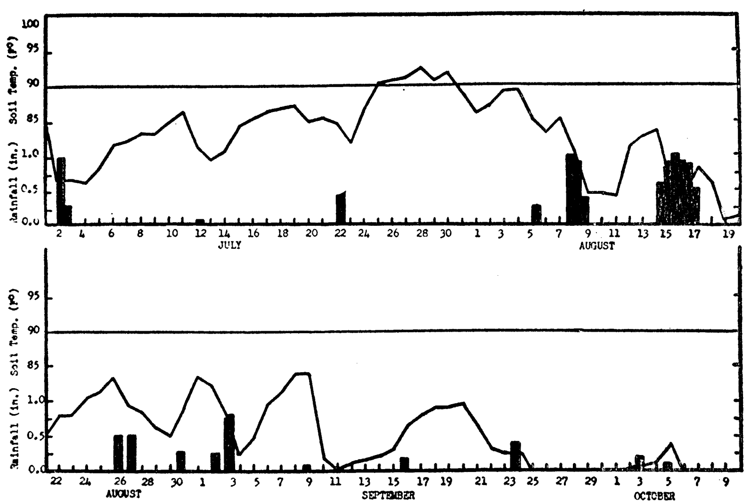

Figure 7.—Daily mean soil temperatures and rainfall data in relation to the plantings made in 1940. This season was especially favorable for fall potato production as indicated by the unusually low soil temperatures and fairly abundant rainfall. See Figures 1 and 5 for similar data for 1938 and 1939.

As indicated by Table X and Figure 9, the rate of emergence of the sprouts from whole tubers was much slower than for cut sets and the more mature tubers (harvested July 6) sprouted and produced plants more rapidly than the immature seed from the earlier harvests.

A summary of the analysis of the data for the plant stands is given in Table XI. When each series (kind of seed) is considered separately it is found that date of harvest was highly significant. In the combined analysis it is found that the difference between whole and cut seed is most highly significant, followed in order by chemical treatment and date of harvest (tuber maturity). Highly significant interactions were also found between these factors.

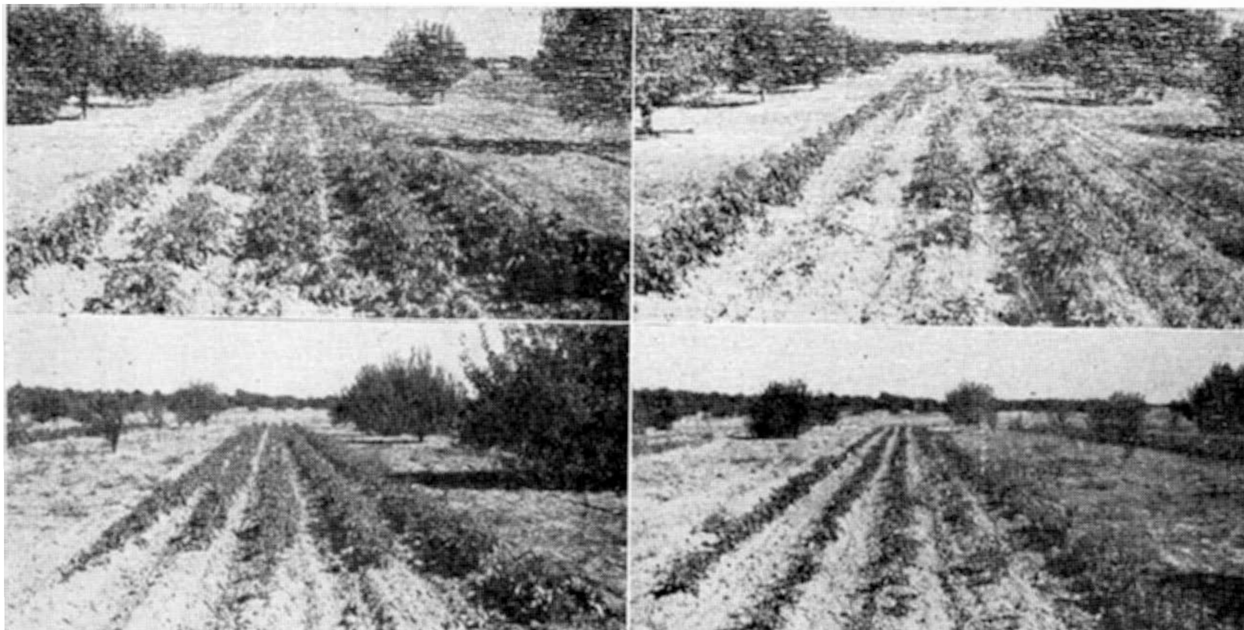

Figure 8.—Photos taken on October 7 to illustrate stands and plant development of the time of harvest series planted July 26, 1940. Pictures to left represent cut seed, those to the right, whole seed. Top pictures for plantings of untreated seed; those at the bottom show plantings made with seed treated with ethylene chlorhydrin.

Table X.—Rate of Emergence, Plant Stands and Yield of Tubers in Relation to Tuber Maturity in the Warba Variety; 1940.

Date of Harvest	Age in days*	DAYS TO 50% UP		PERCENT EMERGED**		BUSHELS PER ACRE		PERCENT OF NO. 1 TUBERS	
		Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut
Treated Seed									
June 15	41	58	37	66	85	37	61	64	65
June 20	36	55	35	53	83	36	62	66	62
June 25	31	56	33	72	74	47	62	61	59
July 1	25	50	33	82	80	59	66	71	51
July 6	20	49	31	79	57	50	49	64	65
Untreated Seed									
June 15	41	76	40	53	78	16	62	29	62
June 20	36	72	36	40	79	22	74	51	69
June 25	31	--	33	--	72	--	64	--	52
July 1	25	56	33	69	87	50	77	68	56
July 6	20	55	33	66	71	53	68	63	57

Tubers harvested on the dates as indicated and stored in cellar until planted. Ethylene chlorhydrin treatment was applied July 22 and the cut sets were prepared on the date of planting, July 26, 1940.

* Number of days from harvesting to planting. The seed harvestedJuly 6 was completely matured.

** "Date of harvest" was a significant factor in each of the four series planted. Differences necessary: Treated whole, 8.2%; treated cut, 8.0%; untreated whole, 5.5%; untreated cut, 6.2%.

STORAGE TEMPERATURE

When tubers harvested in the spring crop are used for fall crop production, it appears to be desirable to hold them in storage for a time before planting. This storage environment should be such that it will favor the so-called after-ripening activities so as to encourage prompt sprouting when the seed is planted. From this point of view, storage temperature appeared to be important and was therefore investigated.

1938

A study of high temperature storage was made in 1938, using tubers harvested June 28 followed by cellar storage. Certain lots were treated with ethylene chlorhydrin on August 4, and two days later a planting was made to the field. At the same time, 24 lots were prepared in baskets of about half-bushel capacity. After weighing, 12 of these were placed at 70° F. and the remainder at 90° in constant temperature cabinets. Field plantings were repeated on August 9, 13, and 17 from the lots kept at the above temperatures.

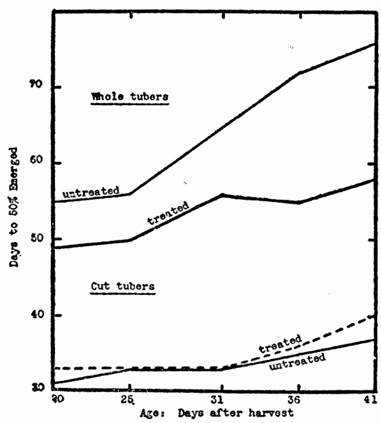

Figure 9.—Comparing the rate of emergence as days to 50% up for tubers of different degrees of maturity when planted as whole tubers and cut sets with and without ethylene chlorhydrin treatment. The most immature seed was harvested June 15, 41 days before planting. The 20 day seed was fully matured when harvested on July 6, 1940.

Table XI.—Analysis of Variance for Plant Stand Data Secured in the Time of Harvest Series for 1940 as Summarized in Table X.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	99	25,872.19		
Between blocks	4	392.54	98.14	2.19
Between rows	4	3,538.34	885.59	19.70*
Date of harvest	4	4,665.74	1,116.44	25.97*
Seed preparation (whole vs. cut)	1	3,733.19	3,733.19	83.12*
Chemical treatment	1	1,288.81	1,288.81	28.70*
Chemical treatment × seed preparation		858.51	858.51	19.12*
Seed preparation × date of harvest	4	6,745.36	1,686.34	37.54*
Chemical treatment × date of harvest	4	1,236.74	809.18	18.02*
Remainder (error)	76	3,412.96	44.91	

* Exceeds the 1% point.

Weight losses were secured at intervals throughout the 11-day period, and since some of the tubers developed decay a count was taken of this at the last interval on August 17. These data are given in Table XII, in which the weight loss is expressed as percentage of the original weight (August 6) and the decay as percentage of the total number of tubers.

The data on rate of sprouting and final percentage emerged are given in Table XIII.

The germination of the seed pieces and the time of emergence of the sprouts varied considerably for the several plantings and in a way that related more to soil conditions in the field than to the treatments given the seed before it was planted. Low stands of plants and somewhat retarded sprouting occurred in the plantings made August 6, 9, and 13, contrasting wtih earlier emergence and a higher percentage emerged for the planting made on August 17. During the time the first three plantings were made, the mean soil temperatures were well above the 90° which is believed to be critical as regards the survival of seed pieces. The other planting was made in association with a series of showers (Figure 1) when the soil was cooled and so wet that it was difficult to get the seed planted. At the time, it was expected that a low stand was inevitable; and therefore the final result proved to be rather unexpected.

1939

In 1939, tubers were placed in refrigerated storage, following harvest of the spring crop, for fall planting in comparison with those kept in a cellar. The humidity was quite high in both locations, with a mean temperature of about 51° F. for the refrigerator as compared to a mean temperature of about 78° F. in the cellar. The duration of the storage at either location varied some for different lots of tubers, depending on the time the seed was harvested or when it was planted. The tubers were removed from cold storage to the cellar a few days before planting as a "warming up" period and to permit treatment with ethylene chlorhydrin when such treatments were a part of the plan.

In one test, seed of eight varieties harvested June 24 was planted on August 11, after 43 days in storage. Prior to planting, tubers of each variety

Table XII.—Weight Loss and Decay of Treated and Untreated Potato Tubers Stored at Two Temperatures.

	Size of Tubers (ozs.)	WEIGHT LOSS (PERCENT) FOR NUMBER OF DAYS IN STORAGE:				Tubers decayed (Percent)
		3	7	9	11	
Stored at 90 F.						
Treated	2	0.83	2.49	5.56	9.14	25.1
Not treated	2	0.63	2.42	5.16	8.93	12.3
Treated	1	0.82	2.84	6.36	10.51	24.1
Not treated	1	0.85	2.48	5.83	9.26	16.3
Stored at 70 F.						
Treated	2	0.54	1.67	3.17	4.71	12.3
Not treated	2	0.41	1.30	2.55	3.86	6.3
Treated	1	0.55	1.78	3.53	4.93	16.1
Not treated	1	0.79	1.95	3.96	5.97	5.8

Tubers harvested June 28, 1938. Treated tubers were treated with ethylene chlorhydrin August 4. Seed shifted from cellar storage August 6 to constant temperatures as indicated. Decayed tubers counted August 17 on 11th day.

Table XIII.—Rate of Sprouting and Stand of Plants For Potato Tubers and Cut Sets in Relation to Chemical Treatment and Storage Temperature; 1938.

Date of planting	DAYS TO 50% UP				PERCENT EMERGED			
	Whole tubers		Cut sets		Whole tubers		Cut sets	
	70	90	70	90	70	90	70	90
Not Treated								
August 6	54	--	39	--	3	--	28	--
August 9	47	56	37	34	6	5	34	22
August 13	51	52	30	31	13	8	30	14
August 17	47	49	23	25	38	15	67	80
Average	43.6	43.3	33.0	30.3	17.9	9.8	36.6	30.7
Treated with Ethylene Chlorhydrin								
August 6	49	--	40	--	6	--	13	--
August 9	33	38	37	32	5	5	35	15
August 13	31	34	33	32	8	10	21	8
August 17	37	31	25	27	64	16	65	45

Spring crop tubers harvested June 28, 1938, and stored in cellar. Ethylene chlorhydrin treatment applied August 4 and the tubers were placed at 70° and 90° on August 6. Eighty to 90 sets were used per treatment.

Table XIV.—Percentage of Germination and Rate of Sprouting for Refrigerated and Cellar-Stored Seed Representing Different Varieties; 1939.

	SEED FROM COLD STORAGE				SEED FROM CELLAR STORAGE			
	Percent Emerged			Days to 50% up	Percent Emerged			Days to 50% up
	Whole	Cut	Ave.		Whole	Cut	Ave.	
Triumph	18	96	57	50	52	89	71	42
Warba	40	60	50	58	29	81	55	52
Red Warba	52	91	72	59	46	94	70	53
Houma	57	81	69	48	29	69	49	48
Earlaine	46	74	60	48	33	71	52	48
Chippewa	52	73	63	48	43	63	53	45
Sebago	28	62	45	54	32	59	46	51
Jersey Red Skin	14	95	55	66	21	87	54	64
Average	38.4	80.2	58.7	53.9	35.6	76.6	56.3	50.4

Seed harvested June 24 and placed in storage June 26. Cold storage temperatures about 51° F., with the mean at 78° in the cellar. Planted in fall crop August 11. Storage interval 43 days.

were given chemical treatment; but for convenience the data for the treated and untreated tubers were combined and the averages are presented in Table XIV.

The soil temperature was relatively favorable at the time this planting was made (Figure 5) and as a result the stands secured were especially good in comparison to those secured for other planting dates that season. On the basis of the average values given, the seed from cellar storage sprouted about 3½ days ahead of that stored in the refrigerator. The greatest difference (8 days) was found in the tubers of Triumph followed by a difference of 6 days in favor of cellar storage in the case of the Warba varieties. There was no significant difference in the stands of plants in relation to the storage temperatures that were used.

Another test conducted in 1939 used seed harvested June 16 and June 21, which was placed in storage in the cellar and refrigerator 3 to 4 days following harvesting. Fall plantings of both whole and cut sets were made on July 29 and August 11. As indicated in Table XV, a much better stand resulted from the August 11 plantings and again the sprouts emerged from the tubers planted from the cellar storage ahead of those from cold storage seed in most comparisons. When the percentage emerged is considered, it is apparent that cellar storage was most favorable for all kinds of seed planted June 29; but in the August planting only that seed harvested June 21 and planted as whole tubers was favored by cellar storage.

In a third comparison of cellar with refrigerated storage made in 1939, certain lots of tubers were kept moist during the storage interval. This moist storage was provided by layering the tubers in excelsior which was kept wet by sprinkling at intervals. The seed used in this test was harvested June 21, placed in storage June 25, and planted to the field on August 5. Two series were planted, one devoted to whole seed, the other to cut sets. Each series consisted of six kinds of seed in a 6x4 arrangement. As the emergence data were taken a strong trend was noted in the stand of plants throughout the four blocks in each series. No explanation for this response is available since the field had been given uniform fallow treatment prior to planting the potatoes and the soil appeared to be uniform at the surface. Since germination of the seed and sprout emergence was seriously affected it seems that the moisture content of the soil must have been at variance. Under these circumstances a correction was applied to the emergence data as presented in Table XVI. This correction was applied according to blocks and therefore did not affect the relative values of the several treatments, since each treatment was represented in each of the four blocks.

With one exception the seed from cellar storage established plants ahead of that from cold storage and as an average this difference was greater when whole tubers were planted.

No significant differences were developed in the data for percentage of emergence in this test in the comparisons of moist vs. dry storage or cellar vs. cold storage.

Still another comparison of storage temperatures is provided in the irrigated trials conducted in 1939. The seed used in the time-of-irrigating test (Table XXV) and the pre-sprouting tests (Table XXIX) originated in in the same harvest of June 21 and was planted in the fall crop in adjacent areas on the same day. The sprouted-seed tests were irrigated on the day of planting as was the first series in the time-of-irrigating test. The seed used in the sprouting test was stored in the cellar, that used in the other came from cold storage. Thus the results presented in Table XVII are for tubers comparable in all respects except for the temperature at which they were stored following harvest and before they were planted in the fall crop.

Table XV.—Rate of Germination and Stand of Plants for Cold Storage and Cellar-Stored Seed Representing Two Planting Dates; 1939.

1939	DAYS TO 50% UP				PERCENT EMERGED			
	Cold storage		Cellar		Cold storage		Cellar	
	Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut
Planted July 29								
June 16 Seed	68	68	65	61	26	35	31	52
June 21 Seed	68	65	70	61	26	35	22	52
Planted August 11								
June 16 Seed	61	46	54	36	48	95	49	88
June 21 Seed	50	35	50	37	6	86	51	74

Tubers stored 3 to 4 days following harvest and removed from cold storage 3 days in advance of planting.

Table XVI.—Germination of Potato Tubers in Relation to Moist Storage in Refrigerator and Cellar; 1939.

	Chem. treat-ment	DAYS TO 50% UP				PERCENT EMERGED			
		Cold Storage		Cellar Storage		Cold Storage		Cellar Storage	
		Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut
Stored moist	None	68	67	67	58	77	73	78	75
Stored moist	E. C.	67	67	64	64	68	60	32	67
Stored dry	E. C.	83	54	53	55	5	73	28	58
Average		72.7	62.7	61.3	59.0	50.0	68.7	46.0	66.7

Triumph tubers harvested June 21, 1939, stored in refrigerator and cellar on June 25, and planted in the field August 5. Storage interval 38 days.

Table XVII.—Comparing Cellar and Refrigerated Storage for Fall Crop Seed Used in Irrigated Plantings; 1939.

	COLD STORAGE		CELLAR STORAGE	
	Whole	Cut	Whole	Cut
Days to 50% up	46	35	31	25
Percent emerged	20	76	43	70
Total yield (Bu./Acre)	12	72	49	86
Percent No. 1 tubers	60	73	70	68

Tubers from June 21 harvest. Planted August 4 with first irrigation at planting time. All lots treated with ethylene chlorhydrin on July 22.

1940

In 1940, tubers were placed in the cellar (mean temperature 76° F.) for comparison with those stored in the refrigerator (mean temperature 50° F.) in fall plantings. Immature tubers of the Warba variety harvested June 15 and fully mature ones harvested July 1 were placed in storage the day following digging and all were removed on August 4 to make a storage interval of 50 and 34 days respectively for the seed of the two harvests. Some of the tubers were treated with ethylene chlorhydrin after removal from storage and all lots were planted on August 12. Three 4x4 squares were planted with 60 sets per plot, the first to cut sets of tubers harvested June 15, the second to cut sets of the July 1 harvest, and the third to whole tubers harvested July 1. As indicated previously, the 1940 season favored the fall crop and good plant stands and yields were possible. (Tables XVIII-a and XVIII-b). Had these series been planted at an earlier date, greater yields probably would have been secured.

As had been found in the trials the previous year, storage of the tubers at 50° slowed up germination of the seed pieces in this test (See Table XVIII-a). For the various lots of seed a difference of 1 to 11 days in the time required for the sprouts to emerge is found in favor of cellar storage. The greater differences were found in the comparisons provided when whole tubers were planted. Similar differences are found in favor of cellar storage when the plant stands are considered, and this combination of early

Table XVIII-a.—Rate of Sprouting and Plant Stands for Potato Seed in Relation to Storage Temperature; 1940.

	Chem. treat-ment	DAYS TO 50% UP			PERCENT EMERGED		
		June 15	July 1		June 15	July 1	
		Cut	Cut	Whole	Cut	Cut	Whole
Cold storage	E. C.	26	31	40	83	79	60
Cold storage	None	37	30	49	79	76	69
Average		31.5	30.5	44.5	81.0	77.5	64.5
Cellar	E. C.	25	25	29	86	87	77
Cellar	None	32	27	41	89	93	65
Average		28.5	26.0	35.0	87.5	90.0	71.0

Tubers harvested June 15 and July 1, and removed from storage August 4. Storage intervals 50 and 34 days respectively. Planted August 12, 1940. Mean temperature for cold storage 50° F., for cellar 76° F.

Table XVIII-b.—Yields for Potato Seed in Relation to Storage Temperature; 1940.

	Chem. treat- ment	BUSHELS PER ACRE			PERCENT NO. 1 TUBERS		
		June 15	July 1		June 15	July 1	
		Cut	Cut	Whole	Cut	Cut	Whole
Cold storage	E. C.	43	40	49	58	60	70
Cold storage	None	37	42	33	50	56	48
Average		40.0	41.0	41.0	54.0	61.0	59.0
Cellar	E. C.	40	53	68	57	62	67
Cellar	None	43	49	47	56	53	63
Average		41.5	51.0	57.5	56.5	57.5	65.0

Tubers harvested June 15 and July 1, and removed from storage August 4. Storage intervals 50 and 34 days respectively. Planted August 12, 1940. Mean temperature for cold storage 50° F., for cellar 76° F.

emergence and better stand resulted in better yields for the seed from cellar storage. This relationship appears to be most evident in the mature seed harvested July 1.

The analysis of the data for percentage emerged is given in Table XIX, which indicates that storage temperature is highly significant as affecting the plant stands and that the percentage emerged for the series planted to whole tubers was significantly lower than that for the two series in which cut sets were planted.

Table XIX.—Analysis of Variance of Plant Stand Data for Seed Storage Tests; 1940 (See Table XVIII).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	47	11,972.00		
Between blocks	3	1,384.40	461.47	5.07
Between rows	3	177.70	59.23	
Between storage treatments	1	1,518.83	1,518.83	16.68*
Between kinds of seed	2	5,417.60	2,708.80	29.76*
Chemical treatment	1	114.16	114.16	1.25
Storage × chemical treatment	1	0.67	0.67	
Kind of seed × storage	2	131.57	65.79	
Kind of seed × chemical treatment	2	313.99	157.00	
Remainder (error)	32	2,913.08	91.03	

* Exceeds the 1% point.

IRRIGATION AND VARIETY STUDIES

1938

In irrigation tests conducted in 1938, water was applied by means of furrows to one series of plots with an adjacent series left unirrigated. Tubers of eight varieties were planted, both as whole tubers and as cut sets, with and without ethylene chlorhydrin treatment. The chemical treatment was applied August 6 and the seed was cut and planted on August 12. Rainfall occurred after the planting was made and therefore the first irrigation was delayed until September 1, with other irrigations being made September 24, October 4, and 15. Data on emergence are given in Table XX.

Table XX.—Rate of Sprouting, Plant Stand, and Yield for Irrigated and Unirrigated Plots; 1938.*

	FURROW IRRIGATION				NOT IRRIGATED			
	Treated E. C.		Not treated		Treated E. C.		Not treated	
	Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut
Days to 50% up	43	40	49	39	47	41	49	40
Percent emerged	44	45	31	47	25	32	15	26
Yield (lbs. per plot)	11	21	4	25	3	6	1	6

* Averages for eight varieties.
Ethylene chlorhydrin treatment applied August 6. Planted August 12, 1938. Four irrigations applied, with first on September 1.

To compare the soil temperature in irrigated and unirrigated plots, the data shown in Figure 10 were taken. Temperatures were secured by means of thermometers which were placed in the centers of the rows (ridges) at depths of 1 to 7 inches. Other thermometers were set at other locations in the row, but since the trends were similar these readings are not presented. The data presented were secured immediately after irrigation water was applied. For this one series of readings it is found that in the morning (8:30) the temperature difference (dry plot minus wet plot) was at a minimum at depths of 5, 6, and 7 inches and then increased during the day. At depths of 1 to 4 inches the least difference was found at the 10:40 period. The maximum temperatures for depths down to 4 inches were found at the 3:10 reading and at 4:30 for depths greater than this. It should be noted that the least difference between the temperatures of the unirrigated and irrigated soils was found at the surface (1.0° to 4.5° F.) and the greatest difference at the 7-inch level (5.0 to 9.5° F.) At depths of 4 to 5 inches (planting depth) the temperature of the irrigated soil was 4 to 7° lower than that for the dry plot.

The soil temperature trends for irrigated and unirrigated plots are further illustrated in Figure 11. To simplify the data, the readings of the 1- and 2-inch levels were averaged and compared with the average for 5- and 6-inch depths. One reading for each day was used and this was taken in the late afternoon between 3:00 and 5:30 o'clock. Irrigations were applied September 24, October 4, and October 15.

1939

Tubers of eight varieties harvested June 23 and stored both in the cellar and in cold storage were planted in the 1939 test. In the preparation of the seed, some lots were treated with ethylene chlorhydrin and some

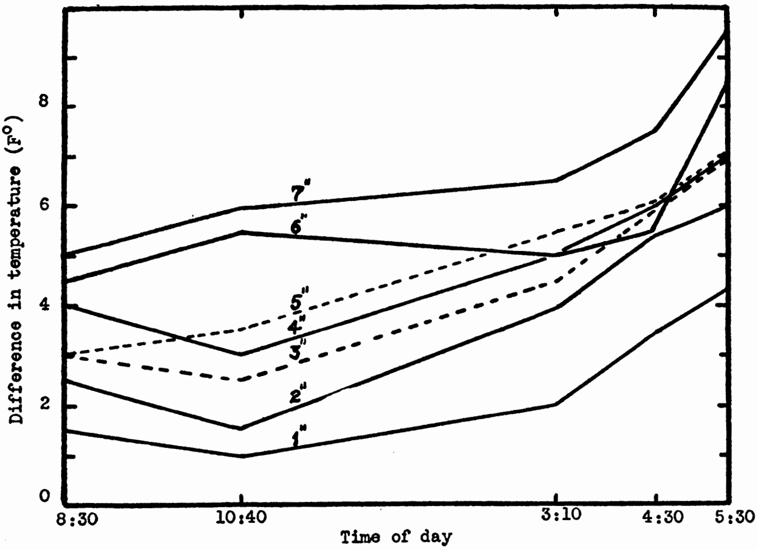

Figure 10.—Showing the difference in temperature between the unirrigated soil and the irrigated soil (unirrigated minus irrigated) for different depths and at different times throughout the day. Data were taken October 15, 1938.

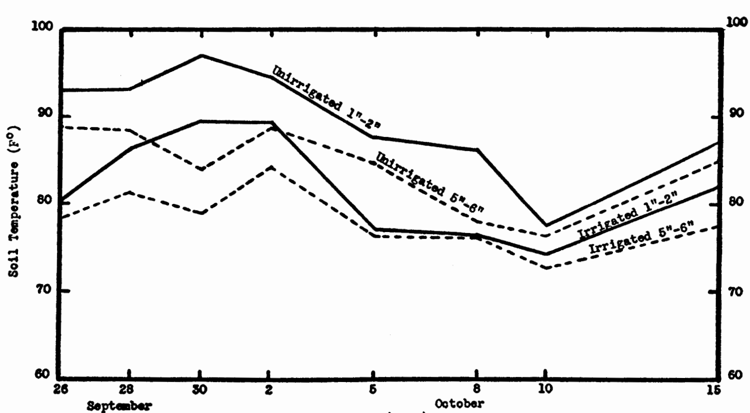

Figure 11.—Soil temperatures for irrigated and unirrigated soils for two depths as indicated by thermometer readings, taken in the late afternoon, for the dates indicated. Average readings for the 1- and 2-inch depths are shown as solid lines with the averages for the 5- and 6-inch depths represented by the dotted lines. (Irrigations applied September 24, October 4, and October 15.)

of the tubers were cut before planting on August 2. Three series of plots were planted. The first was irrigated by an overhead (Skinner) system, the second by furrows, and the third was left unirrigated. As in 1938, the land had been used in the production of a spring crop of beans. The irrigated series were watered the day following planting. Heavy rains followed this, so further irrigations were suspended for about 15 days. After that time they were made at about weekly intervals throughout the remainder of the season. The seed from cold storage was slower (2 to 12 days for the several lots) in getting the sprouts up and with one exception produced lower stands and lower yields. As in the 1938 season, yields were reduced somewhat by low plant stands and by the termination of the growing season before full maturity was attained (Table XXI). The best yield secured in this test was about 50 bushels per acre with about 60 percent of the tubers grading out as No. 1. Yields of five of the eight varieties are shown in Table XXII.

1940

A similar test, involving both varieties of potatoes and methods of applying irrigation water, was conducted in 1940 (Table XXIII-a and XXIII-b). The seed used was harvested June 28 from a spring-crop and the planting was made on August 2, in plots following spring-crop snap beans. All land, including the unirrigated plot, was irrigated about a week before the soil was prepared for planting the fall crop. Seed of six varieties was planted and because of the results secured the previous season only cut sets from untreated tubers stored in the cellar were used. The varieties were arranged in a 6x5 planting in the three series (Skinner, furrow, and unirrigated) with 60 sets planted in each plot. The first irrigation was made on the date of planting and with agreeable season the yields were especially good. The growing season extended until November 9, allowing the crop to attain full maturity; and as a result a large proportion of the tubers sized out in the No. 1 grade.

Table XXI.—Rate of Emergence, Plant Stands and Yields for Various Kinds of Seed and Irrigation Treatments; 1939.*

	TUBERS TREATED WITH E. C.				Untreated; cut
	Planted whole		Planted cut		
	Cold Storage	Cellar	Cold Storage	Cellar	Cellar
Days to 50% up					
Spray irrigated	48	45	40	38	40
Furrow irrigated	67	59	46	39	38
Not irrigated	75	71	75	63	71
Percent emerged					
Spray irrigated	19	39	45	63	58
Furrow irrigated	15	38	47	63	60
Not irrigated	16	25	15	4	4
Yield as pounds per plot					
Spray irrigated	19.9	24.4	41.7	41.7	42.5
Furrow irrigated	4.9	21.0	31.5	39.3	43.9
Not irrigated**	----	----	----	----	----

Planted August 2, 1939, with the first irrigation applied August 3.
* Average results for five varieties.
** No yield data taken.

Table XXII.—Rate of Emergence, Plant Stands and Yields for Seed of Five Varieties of Potatoes in Relation to Irrigation Treatments; 1939.

	Houma	Triumph	Warba	Earlaine	Cobbler
Days to 50% up					
Spray irrigated	37	35	46	43	45
Furrow irrigated	42	35	46	44	51
Not irrigated	70	70	75	72	74
Percent emerged					
Spray irrigated	54	55	49	28	38
Furrow irrigated	55	50	51	51	34
Not irrigated	16	12	15	6	15
Yield in pounds					
Spray irrigated	48.3	43.7	39.5	15.9	21.8
Furrow irrigated	35.7	43.3	31.7	11.5	18.3
Not irrigated	---	---	---	---	---

Data represents averages for several kinds of seed (See Table XXI).
* No yield data taken because of low plant stands.

Table XXIII-a.—Rate of Emergence and Plant Stands for Six Varieties of Potatoes in Irrigation Studies; 1940.

	DAYS TO 50% UP			PERCENT EMERGED*		
	Spray	Furrow	Unirrig.	Spray	Furrow	Unirrig.
Warba	28	30	39	68	57	32
Red Warba	28	30	39	66	55	26
Triumph	26	25	41	61	58	21
Houma	29	30	43	34	57	12
Cobbler	31	34	48	50	44	11
Earlaine	29	29	43	41	33	16
Average	28.5	29.7	42.2	53.3	52.3	19.8

* Differences required for significance: Spray irrigated, 19.4%; furrow irrigated, 14.3%; unirrigated, 9.3%.

Table XXIII-b.—Yield of Six Varieties of Potatoes in Irrigation Studies; 1940.

	BUSHELS PER ACRE			PERCENT NO. 1		
	Spray	Furrow	Unirrig.	Spray	Furrow	Unirrig.
Warba	161	125	19	94	91	72
Red Warba	157	110	17	94	91	55
Triumph	139	97	11	93	92	59
Houma	81	86	9	89	87	35
Cobbler	88	64	6	87	79	43
Earlaine	71	61	7	88	85	31
Average	116.2	90.5	11.5	90.8	87.5	49.2

Seed harvested in spring crop June 28, 1940 and stored in the cellar. Fall crop planted August 2, using cut sets from untreated tubers. First irrigations applied at time of planting. Crop harvested November 11.

Table XXIV.—Analysis of Variance of Plant Stand Data for Irrigation Test; 1940 (See Table XXII).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	89	43,103.06		
Between blocks	4	745.89	186.47	1.10
Between varieties	5	9,735.93	1,947.19	11.51*
Between irrig. treatments	2	19,984.29	9,992.15	59.07*
Varieties × irrig. treatments	10	1,234.64	123.46	.73
Remainder (error)	68	11,402.31	169.15	

* Exceeds the 1% point.

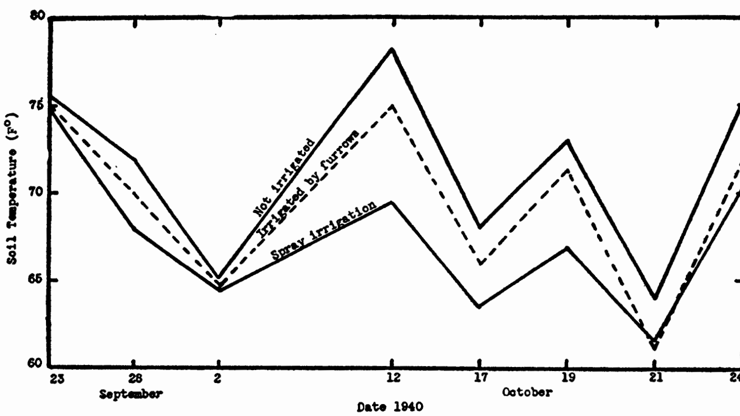

Figure 12.—Soil temperature data secured as thermometer readings at seed depth for plots irrigated by furrows, by the overhead spray method and for those not irrigated. Each point represents an average of three readings for different plots in the series.

The analysis of the data for plant stands (Table XXIV) indicates that significant differences are found between varieties. When the data for the entire experiment are considered, irrigation treatment, as would be expected, was found to be the most significant factor, although the variety factor was highly significant.

Figure 12 illustrates the soil temperatures found at seed depth in the three series. The temperatures represent averages for three readings secured in connection with soil moisture determinations by the method of Bouycous and Mick.* Figure 13 is a general view of the irrigated plots taken on October 7, 1940.

TIME OF APPLYING IRRIGATION WATER

The irrigation tests in 1938 suggested that the time of applying the water is of some significance in fall potato production and therefore tests giving more detailed attention to this subject were made in 1939 and 1940.

* Michigan Agricultural Experiment Station Technical Bulletin 172 (1940).

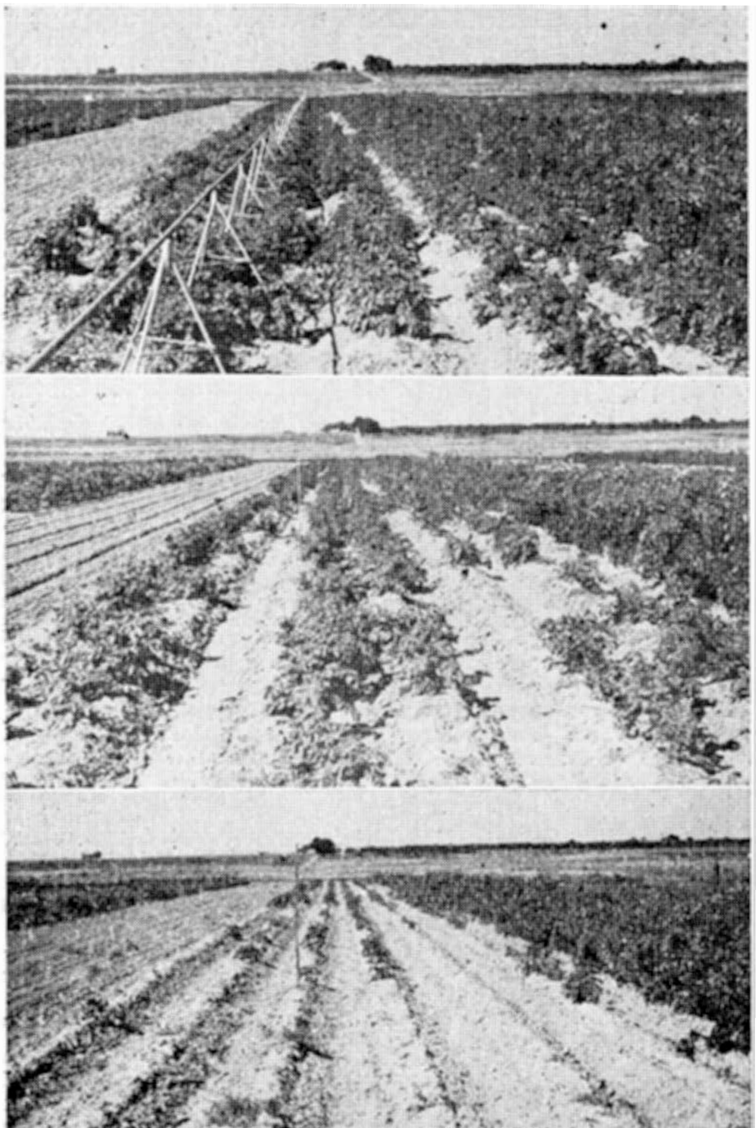

Figure 13.—General views of the irrigated series taken October 7, 1940. Top to bottom: Irrigated by overhead spray (Skinner line), irrigated by means of furrows, and unirrigated.

1939

The 1939 tests consisted of four series of plots, each a 4x4 square. The experimental area was laid out in a field which was prepared late and after considerable weed growth had taken place; as a result, the moisture supply in the soil was relatively low at the time the potatoes were planted. The seed used in these tests came from a June 21 harvest and was from cold storage. Four kinds of seed were prepared and planted in each series, with 65 sets per plot and with guard rows to the outside and a buffer row between each series of four rows. Series 1 was irrigated first at the time of planting (August 4), series 2 one week later, series 3 two weeks after planting. The fourth was left unirrigated. After the initial irrigation the plots were watered at about weekly intervals. A rain during the week the planting was made was the last for the 1939 season. The irrigations were applied by the furrow system.

The results of this test are given in Table XXV. The analysis of the data, presented in Table XXVI, indicates that the stands of plants were significantly affected by the irrigation treatments and also by the method in which the seed was prepared. A significant interaction between the irrigation treatments and kind of seed indicates that tubers planted uncut were more indifferent or less responsive to the irrigation treatments than were the cut sets.

1940

A test similar to the one just described but with some modifications, was planned in 1940. Five irrigation treatments were applied to plots 18′x65′ arranged in a Latin square and protected on all sides by suitable buffer and border plantings. The water was applied in furrows between the rows. A large furrow or ditch at the head of the field served to distribute the water to the proper rows and plots in block 1, while a similar furrow between block 1 and 2 collected the "run-off" from the first and alowed the water to be re-distributed to the plots in block 2. Similar furrows between the other were used to collect and distribute the water to the desired plots according to the requirements for the Latin square arrangement.

Each of the above plots accommodated six rows and these were seeded to whole and cut tubers representing three varieties. The planting was accomplished with a mechanical planter; and therefore, for convenience, the same kind of seed was planted the entire length of the row which traversed the five blocks. Thus the varieties or kinds of seed had the same positions (were in the same rows) for any one tier of plots (row in the square) but the positions were randomized in going from one tier to the next.

The potato planting followed spring tomatoes and the entire field was thoroughly irrigated after the tomato plants were removed. The potatoes were planted on August 13 and the following day one series of plots was irrigated. It was planned to bring other series under the irrigation treatment at about weekly intervals but heavy rains following planting necessitated changes in this schedule as indicated in Table XXVII.

An analysis of the data for plant stands (Table XXVIII) shows that varieties was the most significant factor in this experiment, followed by irrigation treatment, indicating that the low stands secured for the plots irrigated immediately after planting were a result of the treatment given. A significant interaction between varieties and kind of seed (whole or cut) indicates that when planted as late as August 13 with the soil conditions as they were, whole tubers might be preferable for the Triumph variety but cut sets probably would be better for the Warba strains. The conclusion

Table XXV.—Relation of Soil Moisture to Stand of Plants, Rate of Emergence, and Total Yield.

	PLANTED AS CUT SETS				PLANTED AS WHOLE TUBERS			
	First Irrigation				First Irrigation			
	When planted	After 1 week	After 2 weeks	Not irrigated	When planted	After 1 week	After 2 weeks	Not irrigated
Treated with Ethylene Chlorhydrin								
Days to 50% up	35	34	38	52	46	47	51	74
Percent emergence*	76	33	27	13	20	21	20	14
Total yield (Bu./Acre)	72	24	22	12	12	17	12	0.5
Seed Not Treated								
Days to 50% up	34	33	35	53	48	51	48	62
Percent emergence*	84	38	25	9	15	19	19	14
Total yield (Bu./Acre)	79	31	17	1.0	7	14	14	1.0

Data secured from planting of August 4, 1939 (Averages for 4 plots).
* Difference between whole and cut sets, for percentage of emergence, are significant in the first two series—irrigated immediately and irrigated after one week—with 12.9% and 12.3% required for the two series respectively.

Table XXVI.—Analysis of Variance of Plant Stand Data for Time of Irrigating Studies; 1939 (See Table XXV).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	63	30,699.75		
Between blocks	3	279.50	93.17	1.93
Between rows	3	386.88	128.96	2.67
Between irrig. treatments	3	11,003.75	3,667.93	75.91*
Between kinds of seed	3	6,580.88	2,193.63	45.40*
Kinds of seed × irrig. treatments	9	10,419.13	1,157.68	23.96*
Remainder (error)	42	2,029.61	48.32	

* Exceeds the 1% point.

The "kind of seed" indicated above includes whole tubers, cut sets, chemically treated, and not treated. The ethylene chlorhydrin treatment had little if any influence on the stand; therefore the variance in this case largely represents differences between whole and cut seed and for the first two series—irrigated immediately, and irrigated at end of first week.

Table XXVII.—Rate of Sprouting, Plant Stand, and Yield in Relation to Varieties, Irrigation Treatments, and Kinds of Seed; 1940.

	Number of Irrigs.	DAYS TO 50% UP		PERCENT EMERGED		BUSHELS PER ACRE		PERCENT NO. 1	
		Whole	Cut	Whole	Cut	Whole	Cut	Whole	Cut
Warba									
Unirrigated		46	25	52	68	41	62	73	79
1st irrig. Aug. 14	7	45	25	52	24	64	42	79	88
1st irrig. Aug. 23	6	44	25	56	65	70	104	80	85
1st irrig. Sept. 21	5	44	25	59	53	69	91	80	88
1st irrig. Oct. 2	3	45	26	56	71	57	102	78	88
Average		44.8	25.2	55.0	56.2	60.2	80.2	78.0	85.6
Red Warba									
Unirrigated		43	25	34	42	31	42	73	82
1st irrig. Aug. 14	7	40	24	21	32	31	57	84	89
1st irrig. Aug. 23	6	44	24	44	53	55	90	89	87
1st irrig. Sept. 21	5	44	25	35	42	46	67	88	85
1st irrig. Oct. 2	3	45	25	36	49	51	77	89	84
Average		44.0	24.6	34.0	43.6	42.8	66.6	87.4	83.6
Triumph									
Unirrigated		34	24	58	49	51	42	77	73
1st irrig. Aug. 14	7	34	24	40	13	60	30	85	86
1st irrig. Aug. 23	6	33	24	52	49	79	52	87	86
1st irrig. Sept. 21	5	36	24	58	35	86	45	85	81
1st irrig. Oct. 2	3	34	24	60	46	79	50	84	84
Average		34.2	24.0	53.6	38.4	71.0	43.8	83.6	82.0

Planted August 13, 1940, and harvested November 12. Seed was harvested in spring crop June 27 and kept in cellar until planted.

Table XXVIII.—Analysis of Variance of Plant Stand Data for Irrigation Time-of-Appliction Tests; 1940 (See Table XXIV).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F values
Total	149	65,404.78		
Between blocks	4	5,272.64	1,318.16	5.28*
Between rows	4	4,650.98	1,162.74	4.66*
Between irrig. treatment	4	10,890.64	2,722.67	10.91*
Between varieties	2	7,086.42	3,543.21	14.19*
Between kinds of seed	1	89.71	89.71	
Varieties × kinds of seed	2	4,086.01	2,043.00	8.18*
Varieties × irrig. treatment	8	836.92	104.61	
Kinds of seed × irrig. treatment	4	2,530.43	632.60	2.53**
Remainder (error)	120	29,961.03	249.68	

* Exceeds the 1% point.
** Exceeds the 5% point only.

that whole seed (for any variety) responded differently in the several irrigation treatments than did cut sets is also substantiated by the finding of a significant interaction between irrigation treatment and kind of seed.

EFFECTS OF STRAW MULCH AND HEIGHT OF RIDGES

Since moisture appeared to be an important factor in the production of a fall crop of potatoes, and soil moisture is affected by both mulching and the height of ridges, tests involving these two cultural practices were made in 1939 and 1940.

1939

The test in 1939 utilized seed harvested June 6 and kept in cold storage prior to treating with ethylene chlorhydrin on August 7. The planting was made on August 12 in fallow ground with four series of plots separated one from another by buffer rows. Each series consisted of three rows or 12 plots with 65 sets planted in each plot. After planting, the soil in the first series was compacted with a corrugated roller which practically erased the ridges formed in planting. The ridges in the second series were elevated by means of a shovel plow, while those in the third series were left as planted with a low ridge, and the fourth series was mulched thoroughly with a bright straw. The soil was in fine condition at planting,

Table XXIX.—Relation of Certain Cultural Treatments to Plant Stands and Total Yield of Fall Potatoes; 1939.*

	PLANTED WHOLE TUBERS				PLANTED CUT SETS			
	Rolled (Flat)	High Ridge	Low Ridge	Straw Mulch	Rolled (Flat)	High Ridge	Low Ridge	Straw Mulch
Days to 50% emerged	57	43	43	39	49	41	37	38
Percent emergence**	14	33	36	41	35	48	58	55
Total yield (Bu./Acre)	0.3	9.1	8.6	14.6	2.0	8.5	15.0	20.0

* Data for Planting of August 12, 1939 (Averages for 6 plots).
** Variances due to cultural treatment and kind of seed are highly significant. Difference required for significance is 6.90%.

with a good rain preceding planting by a few days (Figure 5). This was the last effective rain for the 1939 growing season. The results are given in Table XXIX.

1940

The test was repeated in 1940 with the elimination of the rolled or compacted series. Year-old (1939 fall crop) Triumph tubers were used as seed. The series were reduced to two rows each (one planted to whole, the other to cut seed) separated by buffer rows. The planting was made in fallow land August 7 and the straw mulch was applied the following morning. Approximately 2½ inches of rain fell in showers closely following planting and other showers followed these in about a week (Figure 7). The soil temperature was therefore relatively low throughout the pre-emergence period. Because of the kind of seed used, the crop matured early and was harvested November 2. Results are shown in Table XXX; and Figure 14 is a reproduction of a soil temperature chart illustrating differences in soil temperature for mulched and unmulched plots. It should be noted that the mulch maintains lower soil temperatures with less diurnal variation. The difference in temperature at seed depth and at the 2-inch level for the high ridge culture is also of interest.

SOURCES OF SEED

Southern-grown Seed, 1939

Seed of the variety Triumph was secured from Louisiana in 1939 and planted in comparison with that taken from the local spring crop. The local seed was harvested June 16 and placed in cold storage (50°) until August 5. It was treated with ethylene chlorhydrin on August 7 and kept in common storage until planted on August 17.

Both the local and Louisiana seed were planted as whole tubers and cut sets in a sandy loam soil. The plots had been given fallow treatment and were well supplied with moisture at planting time, but received no effective rainfall through the remainder of the season. Two series were planted in 4x4 Latin squares, with 65 sets per plot of a single row 70′ long. (Table XXXI.)

Pre-sprouted Seed

A rather definite relationship had been found between the rate of sprouting and the final percentage of germination or the plant stand in the various field and laboratory studies, with prompt emergence of sprouts being conducive to a high plant stand. The longer the seed pieces remained

Table XXX.—Relation of Straw Mulch and Height of Ridge to Emergence of Sprouts and Yields in Fall Crop Potatoes; 1940.

	PLANTED AS WHOLE TUBERS			PLANTED AS CUT SETS		
	Straw Mulch	High Ridge	Low Ridge	Straw Mulch	High Ridge	Low Ridge
Days to 50% up	19	16	14	19	15	12
Percent emerged	47	93	96	17	92	93
Yield (Bu. per Acre)*	18	41	67	6	52	60
Percent No. 1 Tubers	48	32	43	41	33	46

Planted August 7, 1940 using sprouted 1939 fall crop seed.
*Variance for cultural treatments is highly significant with a difference of 13.5 bu. per acre required for significance.

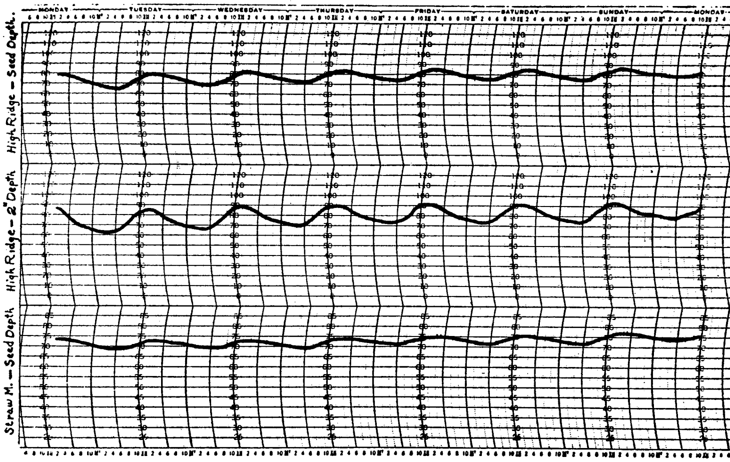

Figure 14.—Temperature record secured on the straw mulch-high ridge series for the week ending August 26, 1940. Top curve for high ridge culture at seed depth; middle curve for 2″ depth with the temperature for the straw mulch series at seed depth shown by the lowest curve. The soil temperature is lower and fluctuates less under the straw mulch. (Note that the scale for this curve has but five degrees per division).

Table XXXI.—A Comparison of Louisiana Grown Tubers with Those Grown in Oklahoma as Seed in the Fall Crop; 1939.*

	LOUISIANA SEED		OKLAHOMA SEED	
	Whole	Cut	Whole	Cut
Series A				
Days to 50% up	37	32	44	36
Percent emerged	80	84	14	63
Total yield (bu./acre)	29	26	3	15
Percent marketable tubers	54	69	5	59
Series B				
Days to 50% up	34	30	70	31
Percent emerged	86	88	32	74
Total yield (bu./acre)	38	28	10	21
Percent marketable tubers	72	79	53	68

* Data for duplicate series.
Planted August 17, 1939 in fallow land. Oklahoma seed harvested as spring crop, June 16, stored in refrigerator and treated with ethylene chlorhydrin before planting.

in the soil at high temperatures in an unsprouted state, the less likely they were to get sprouts up to establish the plants. Under the circumstances it appeared that allowing sprouting to take place before the seed is planted should aid in securing a stand, and tests of this practice were therefore undertaken.

1939.—Two series were planted in 1939, the first using tubers harvested June 16 from cellar storage. The tubers were treated with ethylene chlorhydrin and stratified in moist excelsior to induce sprouting, 21 days in advance of planting. Some of the tubers were cut before placing them in the excelsior. This series was planted June 29 in fallow ground without irrigation. The second series was pre-sprouted 14 days before planting on August 4. The seed was harvested June 21 and was planted along with the "time of irrigating" series for 1939. This second series was irrigated at regular intervals, with the first irrigation at planting time. Both series were planted as 4x4 Latin squares with 65 sets per plot. Data are given in Table XXXII.

Pre-sprouting, as would be expected, proved most beneficial in the first and unirrigated planting, with the most significant difference being found when whole tubers were planted (See Table XXXII). With more favorable soil conditions in the later irrigated planting, all seed lots sent up sprouts surprisingly early and there was no significance in the differences in stand and yield between sprouted and unsprouted seed.

Table XXXII.—Pre-sprouting of Potato Seed in Relation to Emergence of Plants and Yield of Tubers; 1939.*

	PLANTED JULY 29; UNIRRIGATED				PLANTED AUGUST 4; IRRIGATED			
	Sprouted		Not Sprouted		Sprouted		Not Sprouted	
	Cut Sets**	Whole Tubers	Cut Sets	Whole Tubers	Cut Sets	Whole Tubers	Cut Sets	Whole Tubers
Days to 50% up	41	28	53	51	25	25	25	31
Percent emergence†	63	46	55	14	58	49	70	43
Total yield (Bu./Acre)	5.9	4.3	6.7	2.0	81	49	86	49

* Averages of four plots.
** Sets cut before sprouting for this planting.
† F values are significant for both planting dates.
Difference required for significance: July 29 planting, 14.8%; August 4 planting, 16.6%.

1940.—A similar test was conducted in 1940, using Triumph seed harvested June 27 and stored in the cellar. Tubers were pre-sprouted by stratification in moist excelsior after chemical treatment on July 20. Other lots were treated with ethylene chlorhydrin on August 5 and the series was planted on August 12. Cut sets from well sprouted tubers harvested in the fall of 1939 were included, making six kinds of seed which were planted in a 6x5 arrangement with 60 sets per plot.

The results of this test, given in Table XXXIII, show that the year-old seed from the previous fall crop emerged sprouts at an early date (50% up in 10 days) and produced a high final stand of plants.

The pre-sprouted spring-crop seed sent up sprouts at about the same rate as the unsprouted seed which was treated before planting. The sprouts appeared in the other lots of seed at progressively later dates in the order: (1) cut sets from untreated tubers, (2) treated whole tubers, and (3) untreated whole tubers.

Table XXXIII.—Rate of Emergence, Stand of Plants, and Yield for Sprouted Seed in Comparison With Unsprouted Tubers and Sets; 1940.

	Days to 50% up	Percent emerged*	Bushels per acre	Percent No. 1 tubers
Seed from 1939 fall crop				
Planted as cut sets	10	94	53	44
Seed from 1940 spring crop				
Pre-sprouted; cut sets	17	69	47	60
Treated; cut sets	17	76	55	63
Not treated; cut sets	20	74	50	66
Treated; whole tubers	26	69	50	54
Not treated; whole tubers	37	48	23	60

* Variance is highly significant, with a difference of 11.3% required for significance.
Planted August 12 in fallow land. 1939 (fall crop) seed was well sprouted when planted. 1940 spring crop seed harvested June 27 and was kept in the cellar until planting.

The stand of plants for the sprouted year-old seed was significantly higher than that for all other kinds of seed, and that for the untreated tubers planted whole was significantly lower than that for the other five kinds of seed. The remaining four kinds produced stands which were not significantly different. As regards the yields given as bushels per acre in Table XXXIII, principal difference is found in the low yield for untreated seed planted as whole tubers, while the percentage of No. 1 tubers was low for the year-old sprouted seed.

Discussion of Field Investigations

SOIL TEMPERATURE

Effect of High Soil Temperature

The results from the field studies appear to confirm the conclusion drawn from the controlled temperature studies that the increased survival for cut sets at high soil temperature is due to increased oxygen absorption through the cut surface. The greater oxygen supply apparently enables the sets to endure a period of high respiration immediately following planting and to survive until the rate declines naturally. This is especially marked in comparing the July 8 and July 15 plantings in the 1939 "time of planting" test (Table VIII). Rain fall preceding the first planting on July 8 resulted in favorable moisture and temperature conditions at this time (Figure 5). On the date of the second planting, July 15, the mean soil temperature had risen to above 90° with maximum temperatures of near 100° on July 15 and 16. Light showers following this time kept the soil temperature fluctuating with the daily mean alternately above and below the 90° level. The sets planted on July 15, when the soil temperature was high largely perished; while a relatively large number of those planted a week earlier survived this same period of high temperatures. This suggests that the seed pieces of the first planting had passed through some change which tended to adjust them to the high temperatures. Observations were made at times on the condition of the sets in the field by removing the soil. These observations indicated that the cut sets of the first planting were holding up well following planting, and sprout development was evident after two weeks, although the emergence of the sprouts was delayed and the final stand was probably reduced some in this planting by heat injury to the sprout terminals. Contrasting with this it was noted that the sets planted on July 15 broke down soon after planting and before sprouting was initiated.

These results indicate that sets planted under more favorable soil conditions may survive at temperatures which are lethal to newly planted seed. As was concluded from the controlled temperature studies (page 15), it is probable that these responses relate to some extent to the respiratory activity of the tubers and sets. Thus the respiratory rate is probably highest at the time of planting, in response to a change to the higher temperatures in the field. The cutting stimulus and that coming from the chemical treatment would also serve to increase the respiratory rate at this time. In this regard it is to be noted that the sets cut from treated tubers were injured most in the July 15 planting which was made when the soil temperature was unusualy high.

Effect of Cultural Practices in Reducing Soil Temperatures

Time of Planting.—The time of planting was found in the field studies to be one of the most important factors affecting the rate of sprouting and stand of plants and therefore the final yield in fall-crop potatoes. Variations in the results for successive plantings made in the same season related to soil factors and especially the soil temperature and moisture supply. Those plantings made in connection with rainy periods when the soil temperature was low were most successful. Planting at times when the soil temperature was high (means above 90°) usually resulted low stands of plants due to high seed mortality, with the damage to the seed pieces taking place soon after the seed was planted.

Comparison of the time-of-planting data with the rainfall data for the respective years indicates the desirability of taking advantage of the temporary lowering of the soil temperature by rainfall when making fall potato plantings. In 1938, the stand of plants for the August 3 planting was best (Table VII), apparently because of more prompt sprouting of the sets and of the lower soil temperatures and rainfall beginning on August 15 (Figure 1). A similar response is found in the 1938 storage-temperature tests (Table XIII); and another instance is seen in comparison of the July 8 and July 15 plantings in 1939 (See above, page 21, and Table VIII).

In general, those plantings made during the first week in August were most successful and it is believed that this is the most desirable planting date, first, because favorable soil conditions are more likely to be found at this time, and, second, because the spring crop seed is aged sufficiently that prompt sprouting may be obtained by cutting alone and without the use of chemical treatment. Such plantings would normally have sufficient growing season to make a crop. Earlier plantings are likely to meet with more hazards in the way of high soil temperatures and lack of moisture and require chemical treatment of the seed to induce reasonably prompt sprouting.

Irrigation.—From the results of the irrigation tests it is evident that the use of irrigation water greatly enhances the production in fall-crop potatoes. This increased yield for irrigated plots is a composite result of three separate responses: earlier sprout emergence, a higher percentage of germination, and better plant development after the stand is established. Irrigation water probably has a dual role, lowering the soil temperature as well as maintaining the soil moisture at a level agreeable to the crop.

Effect of Irrigation on Soil Temperature.—That irrigation water may be used effectively to lower the soil temperature is illustrated by data secured in 1938 (Figures 10, 11 and 12). These data were taken in September and October and hence do not show the maximum difference which would be found earlier in the season when prevailing temperatures are higher. They indicate, however, that the difference between the "dry" and irrigated plot is greatest immediately after the irrigation is applied and decreases gradually until a second irrigation causes the difference to widen again. The trends in the temperatures at the two depths in the irrigated row is somewhat different in that the temperatures of the surface soil and that at a 5- to 6-inch depth are most similar just after irrigating (September 24, October 4, and October 15) and tend to become increasingly different in the interval betwen irrigation applications. These data show that the soil temperature for irrigated plots is somewhat lower than that for unirrigated ones and that the difference varies in relation to several factors, such as time of day, depth in the soil, etc. Two favorable relationships are found in that (1) the greatest differences are found at the time of day when the soil temperature is at a maximum, and (2) the temperature difference between irrigated and unirrigated soils increases with depth in the soil.

Effect of Irrigation on Plant Emergence.—In 1938, as indicated in Table XX, the emergence for the unirrigated series was slightly retarded and the final stand somewhat reduced over that for the irrigated plots. The response for the various kinds of seed was somewhat similar for the two series of plots, with the whole tubers planted without chemical treatment being slowest to emerge and producing the lowest stands and yields. The germination of sets in this test was low even for the irrigated series and it appears that the condition of seed at planting time might have been in part responsible for this result. It is also believed that earlier and more frequent irrigations would have been helpful.

In 1939, when the fall potatoes followed a spring crop of snap beans, irrigation hastened sprout emergence and improved the final stand as compared to the unirrigated series. It should be noted, however, that unirrigated plantings made in fallow ground at about the same time developed even better stands but were less productive than the irrigated plots. Low soil temperatures and rainfall during the first three weeks in August were favorable to the unirrigated plantings made in the fallowed land but a deficiency of moisture later in the season curtailed the yields for unirrigated plantings.

In 1940, as indicated in Table XXIII, the seed germinated promptly, especially when irrigated. As an average, more than 10 days were gained in the time of emergence in favor of irrigation. The final plant stand was increased by more than 100 percent, and even greater differences were found in the yields of tubers.

Methods of Irrigation.—Applying water as an overhead spray appears to have some advantage over the furrow method, apparently in relation to the lower soil temperatures which result when the water is applied by the former method. (See Tables XXI to XXIV.) Figure 12 shows temperature differences, and Figure 13 illustrates the plant development for these irrigation treatments as found on October 7, 1940.

Time of Applying Irrigation Water.—In the 1939 tests of time of applying irrigation water, it was apparent that sprouting and emergence were favored by irrigating at planting time and even greater differences in yield resulted in favor of early irrigation. (Table XXV.) This is especially true for the seed planted as cut sets, while the germination for whole tubers remained at a low level for all the irrigated series. It is evident that cut sets suffered considerable loss during the first week in the dry unirrigated soil, since the stand was reduced by more than 50 percent when the first irrigation was delayed a week.

In 1940, the principal difference in plant stands as resulting from the irrigation treatments was a lowering of emergence for the plots irrigated at planting time and just before the 4.7-inch rain which came August 14 to 17 (Table XXVII). Under the circumstances it appears that the soil became "water-logged" for a time to the detriment of the newly planted seed. With the soil in this condition, whole tubers held up better than cut sets in the Warba and Triumph varieties, the Red Warba being exceptional in this regard.

A related response was noted in a straw mulch series in 1940 (See Table XXX) where the stand was reduced considerably by excessive moisture in the soil under the mulch following a 2.25-inch rain. Here again the stand for cut seed was reduced more than that for whole tubers.

The tests involving time of irrigation indicate that pre-emergence irrigation is desirable when high temperatures and a lack of moisture prevail at planting time, but that low soil temperatures in association with heavy rainfall may make pre-emergence irrigations unnecessary or even undesirable. It is apparent from the data given in Tables XXV and XXVI that in 1939 sprouting and emergence were favored by irrigating at planting time, and even greater differences in yield resulted that year in favor of early irrigation. With the soil temperature at planting time varying around the critical point as regards the life of the seed pieces (about 90° F.), it is to be expected that irrigations during the pre-emergence period might frequently make the difference between successful plant stands and failures.

Straw Mulch.—In 1939, the straw mulch appeared to be of some benefit with reference to the stand of plants when whole tubers were planted and especially as regards the final yield of tubers for whole or cut seed (Table XXIX). With this rather late planting and for a dry season it appears that the straw was most beneficial in conserving the moisture which was available in the soil at planting time, although the temperature factor can not be disregarded entirely.

In 1940, with excessive rainfall and low soil temperatures, the straw mulch proved to be very detrimental to the stand of plants and yield of tubers, as shown in Table XXX, and this was especially true when cut sets were planted. This result is similar to that obtained in the "time of irrigation" test this same year (See page 39).

From the results of these two tests with straw mulch it appears that the value of this treatment depends upon seasonal conditions and especially rainfall. Since the precipitation during the early part of the 1940 season was unusually high when the straw proved to be detrimental, and because high soil temperatures are not unusual at planting time it is logical to assume that the straw mulch would be practical in fall potato production.

In the spring-planted crop the straw may prove to be detrimental if applied to early (before the plants emerge) because the soil temperature is naturally low and the moisture content is high at this time. In the fall crop the situation is somewhat the reverse of this, in that moisture deficiencies and high soil temperature are most likely to be limiting factors at planting time. Thus for the fall crop the straw mulch would probably be most beneficial during the pre-emergence period, immediately following planting.

Height of Ridges.—The results of the 1939 ridging studies, given in Table XXXI, show that compacting the soil after planting slowed up the rate of emergence and reduced the final stand and yield. Similarly, there was some tendency for the high ridge to delay the emergence of sprouts and to lower the stand of plants. In 1940, the high ridge tended to delay the emergence of the sprouts and to reduce the stand slightly, and an even greater reduction in yield resulted. (Table XXX.)

From these results it is concluded that a high ridge is not as satisfactory as a moderate to low ridge in fall crop production. Low yields may result in association with slower emergence of sprouts and lower plant stands. Both temperature and moisture data were secured in 1940 and from these it appears that the difference in temperature between the high and low ridge was not great (Figure 15). However, in September and October the moisture content was lower in the high ridge where the soil dried out more readily than that in the low ridge or mulched areas. From these observations it is assumed that a deficiency in moisture during the latter part of the 1940 season was responsible in part for the reduced yield for the high ridge culture.

DORMANCY OF SEED

Early sprouting and emergence of the sprouts following planting is highly desirable, first, because the seed mortality at high temperatures increases as sprouting is delayed, and, second, because the growing season is limited and factors conducive to earlier maturity in the crop must be considered. The problem posed by the dormancy of spring-grown seed at the time of planting the fall crop was studied from two directions: (1) By seeking a substitute kind of seed from other sources, and (2) by seeking methods of treating the spring-grown seed to break its dormancy.

Source of Seed

Spring-crop Seed from Further South. The use, as seed for the fall crop, of potatoes grown in the more southern states and harvested some four to six weeks ahead of the Oklahoma spring crop was tested several times in the work done prior to 1938.* This southern seed has generally responded quite favorably. It has been harvested sufficiently long to be capable of prompt germination when planted in the fall crop in Oklahoma and has not lost the apical dominance as has year old seed such as might be held over from the previous fall crop or that which might have been saved from the seed used in planting the spring crop. In the test made in 1939 (Table XXXI), the Louisiana seed sprouted more rapidly than the Oklahoma-grown seed, with a higher percentage of stand and a greater yield. Sprouting was delayed a little in the Louisiana seed when the tubers were planted whole, but for this 1939 test there was not any significant difference in the percentage of stand and the yield was actually greater for this whole seed than that for cut sets. This contrasts with the results with Oklahoma seed, where cut sets are decidedly superior to whole tubers in percentage of stand, time to come up, and yield.

Year-old (Fall-crop) Seed.—The sprout emergence in the case of the fall-grown (year-old) seed used in the pre-sprouting tests in 1940 was exceptionally prompt and a very good stand resulted, but the yield was just average with a low average size in the tubers that were produced (Table XXXIII).

Seed held over in storage a long time loses its apical dominance and sprouts from every eye and perhaps from several buds in each eye. Thus, when planted, each seed piece sends up several sprouts to establish several plants in each hill. (See Figure 15.) Furthermore, these plants mature about two weeks ahead of the more normal plants produced by younger seed. Thus, because of multiple sprouting and early maturity, the potentiality for production is reduced for old seed.

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* See footnote on page 16.

Figure 15.—The absence of apical dominance in year-old seed results in multiple sprouting and the production of several plants in each hill. The lower photo shows two hills from such seed with five weak plants each as contrasted with one plant per hill from spring-grown seed.

One point relative to this old seed must not be overlooked, however: With early sprout emergence and early maturity of the crop, this kind of seed would be favored over the spring crop seed in seasons when early fall frosts shorten the growing season.

Treatment of Spring-grown Seed

Use of Ethylene Chlorhydrin.—Comparisons of tubers and sets treated with ethylene chlorhydrin with untreated seed were made in connection with most of the studies during the three years. Results of these tests all appear to indicate that as the tubers become older (in storage) a point is reached where treatment with ethylene chlorhydrin is unnecessary. This appears to relate to the status of the rest period in the tubers, and it appears that in time this internal condition is such that cutting alone provides sufficient stimulus to sprouting. In fact, when cut sets used in August plantings are considered, the chemical treatment seems to be detrimental to plant stands.

When whole tubers were planted, ethylene chlorhydrin treatment hastened the sprouting of spring-grown seed planted throughout a rather wide planting season; but for cut sets this was true only in early (July) plantings.

These results are especialy favorable in demonstrating that the use of cut sets eliminates the necessity of using chemical treatment to hasten sprouting. The use of the ethylene chlorhydrin seed treatment has always been objectionable from the grower's point of view, since he may have difficulty in locating a supply of the chemical, and its application to the seed is, for him, a rather technical procedure. Improper application of the treatment might be quite destructive to the seed tubers in some instances and in others be harmless but ineffective.

Cutting the Tubers.—That freshly cut sets are superior to whole tubers or suberized sets for fall plantings of potatoes which are made at a time when soil temperatures are high was very clearly demonstrated in the field plantings as well as in the controlled temperature studies. With very few exceptions the cut sets sprouted more promptly with a higher percentage of germination, and both these responses were conducive to higher yields in the fall crop. Under the circumstances it appears that the practice of planting whole tubers is not the best and that more profitable yields might be secured by planting cut seed.

In the 1938 tests involving time of harvest and planting, it is evident that the cut sets sprouted earlier than whole tubers, except for some lots in the first planting. (Table VII, Figure 3.) The emergence trends for the August 3 planting (Figure 4) appear to relate to the status of the rest period in the tubers and it appears that in time internal condition is such that cutting alone provides sufficient stimulus to sprouting and chemical treatment is unnecessary and may even be injurious or deterimental. The 1939 results (Table VIII and Figure 6) agree with those secured for 1938, in that the cut sets germinated more promptly and to a greater extent than tubers planted whole. Again in 1940, the stands of plants secured (Table XIII) are highly in favor of cut seed, with no advantage indicated for chemical treatment.

The principal exceptions to the advantage found for cutting spring-grown tubers occurred during periods of heavy rainfall in connection with the 1940 irrigation studies and with the year-old seed used in the straw mulch studies in that same year. (See pages 39 and 43, and **Tables XXVII, XXVIII, and XXX.**) When the soil temperature data for 1940 are considered (Figure 7) it is found that the temperatures are unusually low and well below the critical point. Thus, it appears that the soil conditions were more comparable to those found in a spring planting and we find whole seed holding up better than cut seed as is sometimes characteristic of spring plantings. This response was found for the Triumph variety throughout all the irrigation treatments and in the unirrigated series where whole seed sprouted better and produced decidedly better yields than cut seed. These results were attained in spite of the slower emergence of sprouts (about 10 days) from the whole Triumph seed.

Among the various procedures used to induce sprouting, the stimulus provided by cutting the tubers was most significant. As pointed out above (page 52), ethylene chlorhydrin treatment appears to be unnecessary after the tubers have passed a certain period in storage. Likewise, the maturity of the tubers seems to have less influence on rate of emergence, stand of plants, and final yield of tubers when cut sets are planted. The 1940 results (Table X) are considered to be especially significant, since the season permited full maturity in these plantings of cut seed and the yields were therefore influenced largely by the plant stands.

Since the yield of tubers is probably the best index of the relative merits of the various treatments used in this test it would be concluded that cut sets planted untreated were most successful, followed by sets from treated tubers with no special preference indicated for the degree of maturity of the tubers when they are cut before planting. Yields secured when whole tubers are planted are low, and this is especialy true of tubers which are immature because of early harvesting.

When early sprouting is the principal advantage for cutting seed, it might be expected that this treatment would not show as great an advantage for the Southern-grown seed or the year-old Oklahoma seed, and this expectation is borne out by the data (Tables XXX and XXXI).

Time of Harvest (Maturity of Tubers).—In the time of harvest studies, tubers harvested late and after full maturity was attained on the vine in the field sprouted more promptly when planted in the fall crop than those harvested in an immature state (harvested some 15 to 20 days earlier) to complete the maturing process in storage. Such a response is to be expected in the light of results published by Rosa (7). This difference in rate of sprouting of immature tubers and mature ones was most evident when whole tubers were planted. It was not of great significance in the 1940 tests when cut seed was planted.

It is apparent that the length of the rest period is related to tuber maturity as determined by the time of harvest, and that these differences are more pronounced in the case of whole seed, especially when untreated tubers are planted. (Figure 9.)

Although these results do not appear to agree with Werner's conclusion (18) that tubers harvested early ripened faster in storage than did those left to mature on the vines, it must be understood that the two studies are not entirely comparable since in Werner's tests there was a difference of two months in the time of harvesting the mature and immature seed and the latter had been out of the ground about two and one-half months before germination tests were started. In this study the most immature seed was harvested but 21 days ahead of the mature seed and it was but 41 days in storage before planting.

The stand of plants and final yields (as given in Table X) indicate a downward trend for whole seed from the mature to the less mature tubers. Thus, in this case early emergence and better plant stands for the more mature seed are favorable to a higher yield of tubers in the fall crop.

Storge Conditions.—From the results of the tests relative to storage temperatures, it appears that an intermediate temperature is to be recommended for holding spring grown tubers until they are planted in the fall crop.

At temperatures as high as 90°, tuber decay is encouraged and the seed value may be reduced. The 1938 trials with storage temperatures in which germination tests were carried out at controlled temperatures (See Table IV) indicated this conclusion even more clearly than the field trials. The storage treatments in the two series were similar, the principal difference between the two tests being that in one the seed was planted to sprout at controlled temperatures and in the other the seed was planted in the field. The decay in storage at the high temperature was increased in those tubers which had been treated with ethylene chlorhydrin before exposing them to the high temperature.

Refrigerated storage at 50° was found to be undesirable in that it slowed up after-ripening of the tubers and caused delayed sprouting after the seed was planted, in comparison with that for tubers stored at 70° to 80° in a cellar.

From the data given in Table XII, it can be seen that in 1938 both chemical treatment and high temperatures increased the weight loss and the decay of the tubers. It appears that the chemical treatment increases the permeability of the periderms, favoring moisture loss as well as gaseous exchange as was shown by Smith (9). The data in Table XIII give no definite indication that the rather brief period of storage at 90° (11 days for the longest interval) hastened sprouting.

On the basis of this test it does not appear that temporary storage of tubers at a temperature of 90° hastens sprouting when they are planted and that the seed value is perhaps lowered some by such storage and especialy when the tubers have previously been treated with ethylene chlorhydrin. This response of chemically treated tubers at high temperatures has been described previously by Denny (3).

A question might be raised as to why the untreated tubers decayed at 70°. This situation is encountered at times in seed secured from the spring crop which develops rots when held in common storage. The decay usually begins at the stem end and appears to be the result of infections by a Fusarium or another decay-producing organism which originates in the field before harvest. Naturally, such tubers are not desirable for seed in planting the fall crop.

In 1939 the comparison of 51° storage (refrigerator) with 78° (cellar) quite definitely indicated that the lower temperature served to retard sprouting in the seed tubers. The data on percentage emergence or plant stands were less consistent and early frosts made the yield data of little significance. With repeated plantings being made in 1938 and 1939 it was found that the influence of "time of planting" (as related to soil conditions in the field) caused considerably more variation in the results than storage treatment of the seed.

With more equable climatic conditions in 1940, more uniform and reliable results were attained. This indicates that storage temperature is worthy of consideration in caring for tubers intended for fall planting. Tubers from cold storage (50°) were found to require a longer time to "come up" (8 to 11 days as whole seed) and usually established a lower stand of plants. With slower emergence of sprouts and a lower plant stand, the yield secured from cold storage seed was somewhat reduced.

Other evidence bearing on storage temperature is available from the irrigation and pre-sprouting tests from which data were taken to compose

Table XVII. The cut seed from the cellar storage sprouted fully 10 days ahead of that from cold storage and produced about 14 bushels more per acre. This increased yield was the result of early sprouting and not due to a better stand. When whole seed was planted, that from the cellar emerged sprouts about 15 days ahead of cold storage seed with a stand increase of more than 100 percent and a yield increase of about 300 percent.

Time of Planting.—As was noted above in connection with the discussion of the effect of high soil temperatures, the time of planting is related to both the soil temperature and to the period of dormancy of the spring-grown seed. In 1938, despite the distortion of the emergence curves due to heat injury, it is evident that the time required for the sprouts to emerge decreased as the time of planting was delayed. Of the various factors involved in the 1939 study, "time of planting" was most significant or effective in conditioning the germination response (See Tables IX and XVIII). Thus a decidedly low germination resulted in the second planting, with the best average stand for the July 29 planting and for the August 5 planting when the cut sets from untreated tubers are considered. A significant interaction between kind of seed and the time of plantings indicates that it is to be expected that the four kinds of seed used in this test would not respond in the same way throughout a series of plantings as made in this test.

Pre-sprouting.—In summarizing the results of the tests with sprouted seed, it can be said that this practice was beneficial at times but sprouted seed was not consistently better than unsprouted seed. Sprouted seed appeared to be best in early plantings and with whole tubers where sprouting is normally slow. When the planting is made late in the season and when the soil conditions are more or less favorable, as in the irrigated planting of 1939 or in the 1940 test, unsprouted seed germinates and gets the plants established practically as early as sprouted seed.

VARIETAL DIFFERENCES

Differences in response to potato varieties in 1938 and 1939 plantings were not very conclusive due to conditions in the field, but the 1940 data were favorable to varieties such as Warba and Triumph which have relatively short rest periods and whose seed sprouted fairly early after planting and matures fairly early after emergence. It appears that sets of the variety Triumph get sprouts up a day or so ahead of the Warba seed pieces, but the latter varieties mature the crop more rapidly and thus are more productive. The variety Cobbler is about a week late in getting sprouts up and matures more slowly after emerging and hence is not considered as suitable for fall planting as Warba or Triumph.

In the 1938 irrigation tests, no outstanding differences were found in the response of the several varieties and therefore only average values are presented in Table XX.

Results of the 1939 irrigation test (Table XXII) show that sprout emergence was most rapid in the seed of the Triumph variety, followed by Houma, with these two varieties being about equally productive.

In the 1940 irrigation tests, the variety factor was highly significant (See Table XXIV). The interaction between variety and irrigation treatment was insignificant, indicating that no importance can be attached to variations in the stands for a given variety as compared to another throughout the three irrigation series. Thus, the same relative differences in plant stands might be expected between the varieties when planted without irrigation as when planted with irrigation.

In the 1940 time-of-irrigation tests, the sprouts emerged from whole Triumph tubers about 10 days earlier than those from whole Warba seed, with relatively slight differences between the varieties when cut sets were planted (Table XXVII).

In genral, it is apparent that seed of Triumph sprouted more promptly than that of the other varieties, being 2 to 5 days ahead of Warba and Houma, 3 to 4 days ahead of Earlaine, and 6 to 9 days earlier than Cobbler. The percentage of emergence was slightly better for the Warba strains, and in total yield they were decidedly better than the other varieties. Slow emergence, a low stand, and slow maturity after emergence all served to reduce the yields in the Cobbler variety.

SUMMARY AND CONCLUSIONS

In this investigation of fall potato production the several causes of crop failures were studied and certain practices were found which were helpful in overcoming these failures. The results indicate that successful production depends upon the accomplishment of two objectives: First, the development of a good stand of plants, followed by, second, the continuous development and maturation of the crop.

1. High soil temperatures were found to be decidedly destructive to potato seed and especially in the range of 90° to 95° F. With mean soil temperatures above 90° at planting time, rather marked reductions in plant stands resulted.
2. The results of this investigation suggest that the seed piece breakdown at high temperatures originates as a physiological disorder and not as a pathological decay. This disorder appears to be similar to blackhearting in that it is associated with a high rate of respiration and a deficiency of oxygen in the tissues of the potato tuber.
3. Because of this relationship, the planting of freshly cut seed pieces was found to be a most helpful practice in securing a satisfactory plant stand when the soil temperature was high or near the critical point. It is believed that the cut surface as related to oxygen penetration to the interior is a significant protection against the breakdown or destruction of the potato sets at high soil temperatures. Although this protection may be but temporary, it is present during the first week or two following planting and when the increased oxygen supply is needed most. It appears that the tubers or sets make certain adjustments to the high temperatures during this critical period following planting and before the new periderm is fully formed. From present knowledge of the respiratory behavior of potato tubers or sets it is likely that this activity is greatest within two or three days after planting in the warm soil, and thus a decline in the rate would roughly parallel the increase in periderm thickness. Furthermore, sprouting may be initiated during this period and it is suggested that in some way the sprouted seed is less subject to the high temperature breakdown.
4. A very definite relationship was found between the rate of sprouting and the survival of seed pieces at high soil temperatures with slow or delayed sprouting associated with low plant stands. From this point of view, cut sets are preferred to whole tubers because they sprout more promptly.
5. Refrigerated storage (50° F.) for the spring crop seed tubers was found to be less desirable than cellar storage (70° to 80° F.) because the lower temperature caused the seed to sprout more slowly after planting in the field.
6. Seed tubers harvested from the spring crop while immature (mid-June harvest) were slower to sprout when planted than tubers which attained full maturity in the field (harvest July 1 to 6) and were less desirable for seed purposes because of this slow response. This difference between immature and mature seed was most evident when whole tubers were planted.
7. Planting sprouted seed hastened sprout emergence, and in the case of year old seed (from previous fall crop) greatly improved the stand. Multiple sprouting in this old seed was found to be a serious fault because the size of tubers was reduced by the competition between the several plants established in each hill. Pre-sprouted spring

crop seed appeared to have some advantage over unsprouted seed in early plantings; but under more favorable conditions, in late plantings, the sprouted seed was not significantly different from unsprouted seed.

8. Ethylene chlorhydrin treatment hastened the sprouting of spring-grown seed and favored the production of a good plant stand. This was true when whole tubers were planted throughout the usual planting season, but was true for cut sets only when the plantings were made early (in July). With August plantings this chemical treatment was useless or even a detriment when the tubers were cut before planting.
9. The time of planting factor as relating to soil conditions was found to be of great importance. The mortality for seed planted when the soil temperature was at a high level was usually high. Prompt sprouting of the seed and the emergence of plants was favored in plantings made when the soil temperature was moderated by rainy weather.
10. Irrigation water was found to be helpful in reducing the soil temperatures during the interval after planting and before the plants were established. In one test, the irrigation at planting time along with an extremely heavy rain proved to be destructive to the seed pieces.
11. Irrigations during the post-emergence period were especially helpful in stimulating uniformly rapid growth in the crop to assure satisfactory yields of tubers.
12. Lower soil temperatures for plants irrigated by the overhead spray method as compared to that for areas irrigated by furrows are assumed to account for differences secured in favor of the spray method in fall potato production.
13. Straw mulch applied at planting time was found to be beneficial as regards moderating the soil temperature and the conserving of the moisture, but in one case abnormally heavy rains following planting caused low stands of plants in the mulched plots.

15. High ridge culture appeared to be unsatisfactory in relation to slowing up the emergence of the sprouts and because of more rapid moisture loss.

15. Early sprouting of seed of varieties such as Triumph and Warba, combined with the tendency for early maturity, make these varieties most suitable for fall crop production. The seed of the Cobbler variety has a longer rest period, sprouts more slowly, and a longer time is required for the crop to mature after the plants get up. This variety is therefore not as desirable for fall plantings as are the Triumph and Warba.

LITERATURE CITED

1. Bushnell, John and F. A. Welton. Some Effects of Straw Mulch on Yield of Potatoes. Jour. Agr. Res. 43:837-845. 1931.

2. Clayton, E. E. Dust Treatments of Cut Potato Seed. N. Y. (Geneva) Agr. Exp. Sta. Bul. 610. 1932.

3. Denny, F. E. The Importance of Temperature in the Use of Chemicals for Hastening the Sprouting of Dormant Potato Tubers. Am. Jour. of Botany, 15:395-409. 1928.

4. Kimbrough, W. D. A Study of Respiration in Potatoes with Special Reference to Storage and Transportation. Md. Exp. Sta. Bul. 276. 1925.

5. Morris, O. M. The Potato Crop. Okla. Agr. Exp. Sta. Bul. 52. 1901.

6. Newton, W. Metabolism of Nitrogen Compounds in Dormant and Nondormant Potato Tubers. Jour. Agr. Res. 35:141-146. 1927.

7. Rosa, J. T. Relation of Tuber Maturity and of Storage Factors to Potato Dormancy. Hilgardia, 3:99-124. 1928.

8. Rosa, J. T. Effect of Chemical Treatment on Dormant Potato Tubers. Hilgardia, 3:125-142. 1928.

9. Smith, Ora. Effects of Various Treatments on the Carbon Dioxide and Oxygen in Dormant Potato Tubers. Hilgardia 4:273-306. 1929.

10. Smith, Ora. Influence of Storage Temperature and Humidity on Seed Value of Potatoes. Cornell Agr. Exp. Sta. Bul. 663. 1937.

11. Stewart, F. C. and A. J. Mix. Blackheart and the Aeration of Potatoes in Storage. N. Y. (Geneva) Agr. Exp. Sta. Bul. 436. 1917.

12. Stuart, William. Potato Production in the South. U. S. D. A. Farmers Bul. 1205. 1934.

13. Thornton, N. C. Oxygen Regulates the Dormancy of the Potato. Contrib. Boyce Thompson Inst. 10:339-361. 1939.

14. Vincent, C. L. and W. W. Pawson. Factors Affecting Potato Seed Piece Decay. Proc. Amer. Soc. Hort. Sci. 30:431-495. 1933.

15. Ward, Norman M. The Rate of Respiration in Potato Tubers at High Temperatures in Relation to Treatment with Ethylene Chlorhydrin. Proc. Amer. Soc. Hort. Sci. 37:871-873. 1939.

16. Waugh, F. A. Garden Vegetables—1894. Okla. Agr. Exp. Sta. Bul. 15. 1895.

17. Werner, H. O. Effect of Cultural Methods and Maturity Upon the Seed Value of Eastern Nebraska Potatoes. Nebr. Agr. Exp. Sta., Res. Bul. 45. 1929.

18. Werner, H. O. The Effect of Maturity and the Ethylene Chlorhydrin Seed Treatment on the Dormancy of Triumph Potatoes. Nebr. Agr. Exp. Sta., Res. Bul. 57. 1931.