GROWTH AND DEVELOPMENT OF THE SWEET POTATO IN RELATION TO GROWTH CRACKING

By

Ahmed A. El-Kattan

Thesis submitted to the Faculty of the Graduate School
of the University of Maryland in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy

1952

ACKNOWLEDGMENT

The writer is deeply indebted to Dr. F. C. Stark, under whose supervision this work was conducted, for his personal and generous help and encouragement, in every phase of this research. The writer's thankfulness and gratitude to Dr. Stark for his exemplary guidance during the past four years can best be expressed in the old Arabic saying: "He who taught me one letter, to him I become a slave."

Acknowledgment is also due to Dr. L. E. Scott, Dr. A. Kramer, and Professor W. A. Matthews for their constructive criticism; and to Dr. R. D. Rappleye for his helpful suggestions concerning the histological phase of this problem.

Finally, the writer would like to express his sincere gratefulness to his wife for her valuable efforts in typing and final presentation of the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

INTRODUCTION

Cracking of sweet potatoes was a serious problem in 1949 along the entire Atlantic Seaboard. On the Eastern Shore of Maryland losses were variously estimated at 30 to 50 per cent, with some fields being completely abandoned (30). During that season the writer was conducting experiments dealing with the effect of various cultural practices on the yield and grade of Maryland Golden and Jersey Orange sweet potatoes (6) at the Vegetable Research Farm at Salisbury, Maryland, and it was therefore possible to study the association of numerous cultural factors with the incidence of cracking.

The phenomenon of growth cracking is not uncommon to sweet potato growers in Maryland. Each year growers observe cracked potatoes during harvesting, but the loss has not been serious enough to attract any attention. In some seasons, cracking of sweet potatoes appears to be serious enough to threaten a crop worth one and a half million dollars in Maryland, and greatly affecting both growers and canners of sweet potatoes.

The severity of cracking in 1949 presented an urgent demand for a remedy to the problem. General and superficial observations did not reveal any specific leads as to a single causal factor. Cracking was observed in storage roots of large and small size, both diseased and sound, and in fields of different soil types, texture, and levels of fertility.

The little research dealing with the problem has been concerned principally with factors increasing or decreasing cracking, and no work has been reported regarding the dause of cracking. Many of the inconsistencies found in the literature seem to be due, primarily, to the general lack of information on the growth behavior of the sweet potato plant and on the appearance of tissues associated with the cracking phenomenon. For this reason, studies were undertaken in 1950 in an effort to explain on physiological and histological bases, the variations in cracking obtained in 1949 as well as to add to the fundamental information concerning the physiology and histology involved in growth and development of the sweet potato.

The studies reported herein are divided into four sections: 1. responses to different cultural practices, 2. growth studies, 3. histological studies, and 4. studies of moisture relations within the plant.

REVIEW OF LITERATURE

Cultural Practices.

The literature concerning the effect of the date of planting, hill spacing, and methods of propagation has been previously covered by the writer (6). Little information is found in the literature regarding the effect of vine pruning on the yield and size of sweet potatoes. Garcia (9) in New Mexico and Starnes (35) in Georgia reported considerable decline in the total yield per acre when sweet potato plants were pruned weekly throughout the season.

Growth.

Weaver and Bruner (43) described the general growth and development of the Yellow Jersey sweet potato. Plants were transplanted to the field on June 1, and after 8 weeks storage roots of 0.2 to 0.5 inch in diameter were observed. On October 3 the plants had 12 well developed storage roots and had a fibrous root system to a working depth of 51 inches.

To the knowledge of the writer, no work has been reported that investigates growth and development of the sweet potato storage roots, as affected by variety, time of planting or weather conditions. Harter and Whitney (12) reported that minimum, optimum, and maximum temperatures for growth of sweet potatoes are 15, 35, and 38° C. respectively. Their assumption, however, was based merely on the condition of the vines. Sakr (29) conducted an experiment where two lots of Porto Rico sprouts were transplanted, and subjected to low and high temperatures of 50-60° F. and 70-80° F. respectively, for a period of two months, after which they were transferred to the field. Plants subjected to cold conditions resulted in slightly lower yields than those subjected to high temperatures. The low temperature treatment also resulted in production of large number of small roots while the high temperature treatment gave fewer potatoes of a larger size which showed symptoms of cracking.

<u>Histology</u>.

Hayward (16) has given a complete description of the structure of the sweet potato storage root at various stages of development, which represents most of the present information on the anatomy of the sweet potato (1, 21). Nowhere, however, have studies been reported on the differences in structure between sweet potato varieties. Studies on wound healing and wound tissue formation in the sweet potato have been reported by a number of investigators. Weimer and Harter (44) found that wound cork in sweet potatoes is formed after 4 days at 70-90° F. temperatures with the humidity at saturation. They further observed that adequate wound cork formation resulted in less rot in storage. Artschwager and Starrett (3) studied the effect of temperature and relative humidity on suberization and wound periderm formation in the sweet potato and gladiolus. Below 55° F., no tissue activity was observed regardless of humidity with the sweet potato. As the temperature increased up to 85° F., high humidity exhibited a more favorable effect on suberization. At temperatures between 85° F. and 95° F., suberization was not increased by relative humidities higher than 75 per cent. The formation of wound periderm, however, was accelerated by an increase in temperature and relative humidity up to 87° F. and 100 per cent R. H. At temperature above 95° F., formation of wound periderm was retarded, and the tissues decayed. Similar to their findings with sweet potatoes, Artschwager and Starrett (4) also found temperature and relative humidity have an effect on suberization and formation of wound cork in sugar beets.

Working with Irish potatoes, Priestly and Woffenden (26) reported that the rate of wound cork formation was doubled by increasing the temperature from 15° C. to 25° C. Weiss and Lauritsen (45) observed that infection of Irish potatoes by storage rots did not occur at a high relative humidity. Artschwager (2), also working with Irish potatoes, found that temperature and humidity affect suberization and wound periderm formation. He found that a high humidity is more important for proper wound periderm formation than for suberization. He also reported that the rate of suberization and wound periderm formation was higher in the Irish Cobbler variety than in the Russet Rural, especially at temperatures below 50° F.

Cracking of Sweet Potatoes.

Growth cracking in sweet potatoes was reported by Harter and Weimer (11) in 1929 when they proposed that the seasonal variation in prevalence of cracking indicates an association with weather conditions. They also called attention to a great varietal difference in susceptibility to cracking and further observed that growth cracking was most serious in better drained soils. Willis (48) at North Carolina found that applications of borax decreased cracking. Lutz *et al.* (20) reported that heavy applications of lime and high levels of nitrogen increased the incidence of cracking. Lutz *et al.* and Nusbaum (23), however, were unable to associate cracking with applications of borax. In

Virginia, soil fumigation has been reported by Mullins (22) as a partial control of cracking. Scott _et al._ (31) in Maryland were unable to influence the amount of cracking by varying rates or sources of nitrogen or by varying soil moisture content. However, a slight benefit was obtained by using D-D(dichloropropene-dichloropropane) as a soil fumigant. More recently Ogle and Scott (25) found that high levels of nitrogen with irrigation increased cracking while soil fumigation did not influence cracking. They also observed that cracking significantly increased towards the end of the season. Ogle (24) was able to reduce cracking in 1951 by using alpha-napthaleneacetic acid as a foliar spray, during August.

Cracking of Irish Potatoes.

Cracking of certain varieties of Irish potatoes during harvest time has been reported to be a serious problem. Werner (46) at Nebraska reported that high turgidity of the tissues of the tubers is responsible for the susceptibility of these tubers to cracking when subjected to a mechanical shock. He found, also, that exposure of freshly dug potatoes to the air for few hours reduces their turgidity and susceptibility to cracking. Results obtained by Werner and Dutt (47) show that varieties differ in their susceptibility to cracking, and that the variety Triumph was among the most susceptible. They found that cutting the roots a few days before harvest was effective in reducing the amount of cracking. They recommend loosening of the upper part of the soil above the roots, especially during moist weather conditions, to accelerate drying and to prevent water absorption through the skin of the tubers. It was further observed that cracking was most severe during cool damp weather and on plants having a large proportion of dead leaves and vines. In an attempt to explain varietal difference in susceptibility to cracking, they found that in susceptible varieties, transpiration is slow, and sugar content in the tubers increases rapidly under cool conditions which may bring differences in osmotic or turgor pressures. They suggest that the structure of the tuber in susceptible varieties, permits central growth to exceed peripheral growth which may be among the direct factors causing growth cracking. Pumphry and Harris (27) also found that cutting the roots before harvest was effective in reducing cracking. No beneficial effect was obtained from destruction of the vines under any conditions, and under cool moist conditions the practice resulted in more cracking.

Cracking of Tomatoes.

Tomatoes are occasionally subjected to both radial and concentric cracking. Studies conducted by Frazier (7) and Frazier and Bowers (8) indicate that radial cracking occurs with the growth of the fruit and expansion of the creases around the stem end, while concentric cracking is caused by imbibition of moisture by the corky tissues at the stem end and the corky spots on the fruit. Frazier and Bowers observed the greatest amount of cracking when a drought period was followed by conditions resulting in a low transpiration rate; and that plants with open foliage and exposed fruits are most susceptible to cracking. They suggest that exposure of fruits to a high temperature and a dry wind affects the ability of the ovary wall to expand. They also found that the fruits are most susceptible between the pink stage and the red stage, and that cracking is apt to originate from an old healed crack or from an injured area on the fruit. Varietal difference in susceptibility to cracking shows that breeding and selection may be the most effective solution to the problem.

Cracking of Apples.

Verner (39) in 1935 conducted a number of experiments dealing with the physiology of cracking in Stayman Winesap apples. He found that exposed fruits on the tree show more cracking than protected or shaded fruits, and that cracks usually occur in modified regions on the fruit such as sunburns, russeted areas, old healed cracks, scab lesions or regions showing spray injuries. The results indicate that environmental conditions resulting in a low evaporation rate favor the incidence of cracking. Verner also determined the osmotic pressure throughout the apple fruit, and found that in cracked fruits, the osmotic pressure was highest at the region of cracking and underneath modified regions of the skin. On the opposite side of these fruits, the osmotic pressure was lowest. Sound fruits, however, did not show such an osmotic gradient. He concludes that cracking is due to the enlargement of internal tissues of the fruit exceeding the extensibility of the outer tissues, and that modified regions on the fruit are not only weak in structure but also underlain by tissues of high osmotic pressures, and would therefore receive more water than the normal parts of the fruit, especially when low evaporating conditions prevail.

Histological studies were conducted by Verner (40) in relation to cracking of apples. These studies indicate that the hypodermal layer of the fruit, rather than the epidermis, is the important tissue involved in cracking. In Stayman Winesap, which is very susceptible to cracking, the cells of the hypodermal layer were found to be stretched tangentically, while in noncracking varieties such as Arkansas the cells of the hypodermis are more or less diametric. In susceptible varieties, failure of the hypodermal layer to keep in pace with the enlarging underlying tissues seems to be the cause of cracking. He explains that periods of hot dry weather, sunburn, russet, and spray injury can limit the extensibility of the hypodermis and causes premature cessation of growth in this layer. Later in the season, conditions of low evaporation cause unusual acceleration of growth in the fruit, and increase the hydration of the tissues. When the limit of extensibility of the hypodermal layer is reached, further expansion of the internal tissues leads to cracking.

Cracking of Cherries.

In 1922 Gardner, Bradford and Hooker (10) attributed cracking of sweet cherries to low elasticity of the skin. Hartman and Bullis (13) found cracking of cherries to be due to an excess of water being taken up either by the roots or through the skin of the fruit. Verner and Blodgett (42) reported that absorption of water through the skin of the fruit is responsible for cracking, and that this absorption is osmotic and depends on the concentration of soluble solids in the fruit juice and the permeability of the skin. Verner (41) more recently found that sprays of Bordeaux mixture, and other calcium sprays, reduce cracking in cherries without any effect on the size of the fruits, or the concentration of the juice, suggesting that reduction in cracking may have been due to the reducing effect of calcium on the permeability of the skin. Studies conducted by Tucker (38) show a varietal difference in susceptibility to cracking. He states that large size, high concentration of soluble solids in the juice, and thin skin together increase the susceptibility of fruits to cracking, and that the most cracking occurs when cherries mature during periods of prolonged rains.

Kertesz and Nebel (17) studied the histological and physiological aspects of cracking in cherries. Their investigations indicate that varieties susceptible to cracking are characterized by epidermal cells of thick inner walls, shallow subepidermal layers of small cells, fleshy tissues of nonuniform cells where large cells are interspersed by groups of small cells, and large vascular bundles. They measured susceptibility to cracking by immersing the fruits in water for various lengths of time and found that incidence of cracking increases with the increase in water absorption by the fruits. The pulp of the susceptible varieties was found to have a high water holding capacity which was attributed to high content of colloidal pectins.

GENERAL MATERIALS AND METHODS

Data concerning the effect of variety, time of planting, method of propagation, and hill spacing on cracking of Maryland Golden and Jersey Orange sweet potatoes, were obtained from the experiments conducted in 1949 and the materials and methods applied were previously described by the writer (6). In 1950 the following studies were made:

1. Effect of date of planting, hill spacing, and vine pruning on the yield, grade, number of storage roots, average weight per storage root, and per cent cracking.

2. Analysis of the weather data of 1949 and 1950.

3. Effect of the date of planting on growth and development of the storage roots of Maryland Golden and Jersey Orange sweet potatoes and the explanation of this effect and its relation to cracking on basis of temperature summations.

4. The mode of development of the storage roots in seven sweet potato varieties, including the increase in the yield per plant, the average weight per root and the number of storage roots per plant. Varieties used were: Maryland Golden, Jersey Orange, Porto Rico, Allgold, B-5999, L-241, and Australian Canner.

5. Histological studies involving microscopic examinations of

normal and cracked storage roots, varietal differences in structure, and micro-environmental tissue activity in Maryland Golden and Jersey Orange varieties.

6. Studies of moisture relations including experiments to determine the effect of various factors on the moisture content and the affinity of the sweet potato tissues to water.

The field work was done at the University of Maryland Vegetable Research Farm at Salisbury, Maryland, where the plots were located on a sandy loam soil. Seed stocks of Maryland Golden, Jersey Orange, and Porto Rico varieties were secured from a stock maintained by the Maryland Agricultural Experiment Station. Stocks of Allgold, L-241 (Recently named Gold Rush), Australian Canner, and B-5999 were obtained from the Oklahoma, Louisiana, Mississippi Agricultural Experiment Stations, and the U. S. Department of Agriculture, respectively. As the potatoes were taken out of storage, they were examined, and those which were diseased were discarded. Three-fourths of an inch of the proximal end of each potato was chipped off in order to select for internal color and to break proximal dominance (37). Just before bedding, the potatoes were dipped in "Puratized Agricultural Spray 5%" at a concentration of 1 part per 5000 parts water.

As the plants were pulled, they were bundled and rolled in wet burlap bags to keep them from drying out before planting. A period of 24 to 48 hours elapsed between the time the plants were pulled from the beds and the time they were set in the field.

The land was plowed, disced, and harrowed preparatory to planting. For most of the tests, sprouts were planted with a transplanter and spaced 15 inches apart, in 32-inch rows. In the hill spacing tests, plants were set by hand with a dibble in order to obtain accuracy in spacing. A 3-9-12 fertilizer was applied in bands at the rate of 1500 pounds per acre, in two split applications, with the first made two weeks after planting, and the second two weeks later. The crop was cultivated and hoed often enough to keep down weeds and grass. Vine turners were attached to the cultivators to keep the vines trained in one direction in accordance with local custom.

In all plots except those concerning studies of date of planting, sprouts were set on May 25. The crop was harvested during the second week of October, and the storage roots were graded, weighed, and counted. The grades used for the purpose of these tests may be described as follows:

<u>Jumbo</u>: Potatoes that are larger in size than the market grade.

<u>Market</u>: Potatoes that are less than 16 ounces in weight, over 1-3/4 inches in diameter, and less than 10 inches in length.

<u>Canning</u>: Potatoes that are smaller in size than the market grade, yet still have a chunky shape with a minimum size of 1-1/4 inches in diameter and 2 inches in length.

More specific procedures for the various studies will be described later with the results. The data obtained were analyzed statistically, using methods as reported by Snedecor (33) and Cochran and Cox (5).

PROCEDURES AND RESULTS

I. RESPONSES TO DIFFERENT CULTURAL PRACTICES

A. Date of Planting.

In 1949 Maryland Golden and Jersey Orange varieties were planted on five successive dates as follows: May 6, May 21, June 6, June 21, and July 6. The data obtained in 1949 (6) indicated that the total yield decreased with the delay in planting. The yields from the first two dates were higher than the third date, and the third date yielded higher than the last two dates. It was also evident that the ratio of market grade to canning grade decreased with the delay in planting. In the first three plantings Maryland Golden outyielded Jersey Orange, while there was no difference between the two varieties when planted on June 21 or July 6. The varietal difference in yield was due to a greater production of jumbo and market size potatoes by Maryland Golden, while there was no difference between the two varieties in the production of canning grade potatoes. Additional information is presented in Tables 1 and 2 showing the effect of the date of planting on the number, average weight, and percentage of cracking of sweet potatoes. The number of storage roots was affected by the date of planting. In both varieties the second date of planting gave the highest number of storage roots followed by the first and third dates. The fourth and fifth dates gave the lowest number with the fifth date producing more storage roots than the fourth date. There was no difference in number of potatoes produced by either variety in any one of the five dates. The average weight of the storage root decreased with the delay in planting, with the first date giving the highest weight

Table 2. Effect of Time of Planting on Yield, Number of Storage Roots, Size of Storage Root, and Cracking of Maryland Golden and Jersey Orange Sweet Potatoes. (1949)

Variety	Date 1949	Yield Bu./A	Number Roots/300' Row	Ave. Wt./Root Lb.	% Cracked
Maryland Golden	May 6	385.4	774	0.50	51.3
	May 21	342.4	1174	0.29	19.9
	June 6	257.1	878	0.29	22.9
	June 21	78.6	298	0.27	45.2
	July 6	108.9	594	0.19	14.3
	Average	234.7	742	0.31	30.7
Jersey Orange	May 6	219.0	772	0.28	10.1
	May 21	249.9	1036	0.24	4.1
	June 6	136.7	706	0.19	6.2
	June 21	70.8	388	0.18	3.1
	July 6	79.3	470	0.17	4.3
	Average	151.3	674	0.21	5.6
Average	May 6	301.9	774	0.39	30.6
	May 21	296.4	1106	0.27	12.0
	June 6	196.6	792	0.24	14.6
	June 21	75.0	344	0.23	24.2
	July 6	93.8	532	0.18	8.3
L.S.D.					
	Date @ 5%	49.6	252	0.05	6.1
	@ 1%	65.9	344	0.07	9.5
	Var. @ 5%	31.5	n.s.	0.02	4.3
	@ 1%	41.7	n.s.	0.03	6.0
Variety x Date	@ 5%	90.1	n.s.	0.09	9.9
	@ 1%	119.8	n.s.	n.s.	12.3

followed by the second, third, and fourth dates among which there was no difference, and with the fifth date giving the smallest storage roots. This was true in Maryland Golden; although in Jersey Orange, the first two dates produced storage roots of similar average weight, and were larger than the roots produced by the last three dates among which there was no difference. The decrease in average weight of the roots of Maryland Golden was very sharp while it declined gradually with Jersey Orange. Comparing the two varieties, Maryland Golden produced larger storage roots than Jersey Orange, especially in the earliest date of planting.

Studying the effect of date of planting on percentage of cracking, it was found that the two varieties behaved differently. In Maryland Golden the percentage of cracking was much higher in the first and fourth plantings than in the other three plantings. In Jersey Orange the date of planting did not affect the percentage of cracking, however, the first date of planting resulted in more cracking than the other four dates among which there was no difference. Regardless of time of planting, percentage of cracking was much higher in Maryland Golden than in Jersey Orange.

In 1950 Maryland Golden and Jersey Orange were planted at three dates: May 11, May 25, and June 22. Data obtained are shown in Tables 3, 4, 5, and 6, and indicate that the total yield decreased with the delay in planting. This decrease was expressed in the decrease in production of the jumbo and market grades, while the canning grade remained constant and was not affected by the delay in planting, thus decreasing the market grade to canning grade ratio. Plantings made on the first two dates produced more market potatoes than canning potatoes, while the third planting produced equal yields of both grades. The two varieties produced equal total yields, with Jersey Orange yielding more of the canning grade at the expense of a lower

Table 3. Analysis of Variance of the Effect of Time of Planting on Yield, Grade, and Number of Storage Roots of Maryland Golden and Jersey Orange Sweet Potatoes. (1950)

Source	D/F	Variance	
		Yield	Number
Variety	1	52.4	20184.0**
Date	2	2142.2**	6287.0**
Replicate	2	36.7	717.0
Variety x Date	2	17.2	256.5
Error (a)	8	37.0	521.5
Total	17		
Grade	2	11710.0**	193329.5**
Variety x Grade	2	464.2**	14587.5**
Date x Grade	4	1924.3**	15267.5**
Variety x Date x Grade	4	23.9	974.0
Error (b)	24	61.5	1290.4
Total	53		

**Significant at odds of 99:1

Table 4. Analysis of Variance of the Effect of Time of Planting on Size of Storage Roots of Maryland Golden and Jersey Orange Sweet Potatoes. (1950)

Source	D/F	Variance Ave. Wt./Root
Variety	1	0.0228**
Date	2	0.0477**
Replicate	2	0.0014
Variety x Date	2	0.0007
Error	10	0.0008
Total	17	

**Significant at odds of 99:1

Table 5. Effect of Time of Planting on Yield, Grade, and Size of Storage Root of Maryland Golden and Jersey Orange Sweet Potatoes. (1950)

Variety	Date 1950	Yield Bu./A. Jumbo	Market	Canning	Total	Ave. Wt./Root Lb.
Maryland Golden	May 11	41.7	255.0	54.4	351.1	0.41
	May 25	14.8	175.6	75.7	266.1	0.27
	June 22	6.0	82.0	64.1	152.1	0.22
	Average	20.8	170.9	64.7	256.4	0.30
Jersey Orange	May 11	15.4	254.7	83.6	353.7	0.31
	May 25	3.6	173.0	126.5	303.1	0.22
	June 22	0.0	58.8	106.9	165.7	0.16
	Average	6.3	162.2	105.7	274.2	0.23
Average	May 11	28.6	254.9	69.0	352.5	0.36
	May 25	9.2	174.3	101.1	284.6	0.25
	June 22	3.0	70.4	85.5	156.9	0.19

L. S. D.	@ 5%	@ 1%
Yield		
Date	42.2	61.3
Date x Grade	39.6	53.8
Variety x Grade	48.5	66.0
Ave. Wt.		
Variety	0.03	0.04
Date	0.04	0.05

Table 6. Effect of Time of Planting on the Number of Storage Roots of Maryland Golden and Jersey Orange Sweet Potatoes. (1950)

Variety	Date 1950	Number of Roots/300' Row			
		Jumbo	Market	Canning	Total
Maryland Golden	May 11	30	484	342	856
	May 25	11	403	585	999
	June 22	5	216	486	707
	Average	15	368	471	854
Jersey Orange	May 11	12	574	555	1141
	May 25	3	495	921	1419
	June 22	0	178	868	1046
	Average	5	416	781	1202
Average	May 11	21	529	449	999
	May 25	7	449	753	1209
	June 22	3	197	677	877

L. S. D.	@ 5%	@ 1%
Variety	126	188
Date	158	230
Variety x Grade	145	201
Date x Grade	161	246

production of jumbos. Regardless of the date of planting, the average weight of the storage roots produced by Maryland Golden was higher than Jersey Orange, and in both varieties this average weight decreased with the delay in planting. With regard to the effect of time of planting on the number of storage roots (Table 6), the data indicate similar results to those obtained in 1949, that is, the second date of planting gave a higher total number of storage roots than the first or the third dates between which there was no difference. Apparently, the number of the large roots was decreased by the delay in planting while the number of the small roots increased. The number of the jumbo potatoes declined with the delay in planting. The first two plantings produced equal numbers of market potatoes and were higher than the third planting, while the second and third dates of planting gave higher number of canning potatoes than the first planting. This was true in both varieties as indicated by the lack of significance in the variety x date x grade interaction. Regardless of the time of planting, the Jersey Orange variety produced more storage roots than Maryland Golden. This difference was due to high production of the canning grade with low production of the jumbo grade by Jersey Orange whereas there was no varietal difference in the number of the market grade potatoes. In general, with the normal growing season, the variety Maryland Golden tended to produce equal numbers of market and canning potatoes, with comparatively high number of jumbos while Jersey Orange produced more canning potatoes than market potatoes with a low number of jumbos.

B. Hill Spacing.

Data obtained in 1949 (6) indicated that when Maryland Golden and Jersey Orange varieties were planted at distances of 6, 12, 18, and 24 inches within the row, the total yield per acre was not affected in either variety. In spacings of 6 and 12 inches, however, the plants produced more canning grade potatoes than in the 18- , and 24-inch spacings. There was a decline in the yield of the jumbo grade as spacing decreased, while the yield of the market potatoes was not affected. Of the two varieties, Maryland Golden outyielded Jersey Orange due to the higher production of jumbos and market potatoes by the former, whereas there was no varietal difference in yield of the canning grade potatoes. Data showing the effect of the different spacings upon the number, average weight, and cracking of storage roots are presented in Tables 7 and 8. The number of storage roots per row decreased as the space between plants increased. A spacing of 6 inches gave a higher number of roots than the 12-inch spacing, while 18- and 24-inch spacings gave the lowest numbers. There was no difference between 18- and 24-inch spacings in number of storage roots per row. Both Maryland Golden and Jersey Orange produced equal numbers of storage roots and responded similarly to hill spacing. Furthermore, in both varieties the average weight of storage roots increased progressively with the increase in distance between the plants, and in each spacing Maryland Golden produced larger storage roots than Jersey Orange. Hill spacing did not significantly affect the percentage of cracking, although the varietal difference in cracking was very striking and in any one of the spacings studied, Maryland Golden had a much higher percentage of cracking than Jersey Orange.

Table 7. Analysis of Variance of the Effect of Hill Spacing on Number of Storage Roots, Size of Storage Roots, and Cracking of Maryland Golden and Jersey Orange Sweet Potatoes. (1949)

Source	D/F	Variance		
		Number	Ave. Wt.	% Cracking
Spacing	3	7361**	0.0109**	9.22
Variety	1	0.0	0.0322**	943.76**
Replicate	2	3058**	0.0003	48.73
Variety x Spacing	3	592	0.0014	71.88
Error	14	415	0.0006	23.97
Total	23			

**Significant at odds of 99:1

Table 8. Effect of Hill Spacing on Yield, Number of Storage Roots, Size of Storage Roots, and Cracking of Maryland Golden and Jersey Orange Sweet Potatoes. (1949)

Variety	Spacing	Yield Bu./A.	Number Roots/300' Row	Ave. Wt. Lb.	% Cracked
Maryland Golden	6"	251.4	1404	0.29	17.1
	12"	231.2	1092	0.33	26.4
	18"	196.5	844	0.35	30.6
	24"	208.9	844	0.42	36.9
	Average	220.4	1046	0.35	27.8
Jersey Orange	6"	181.2	1226	0.23	9.0
	12"	180.9	1126	0.26	10.5
	18"	172.7	924	0.30	10.0
	24"	160.3	902	0.30	13.9
	Average	173.8	1044	0.27	10.9
Average	6"	216.3	1316	0.26	13.1
	12"	206.1	1110	0.29	18.5
	18"	184.7	884	0.32	20.3
	24"	184.6	874	0.36	25.4

<u>L. S. D.</u>

Spacing	@5%	n.s.	152	0.03	n.s.
	@1%	n.s.	210	0.04	n.s.
Variety	@5%	23.4	n.s.	0.02	4.8
	@1%	30.8	n.s.	0.03	6.5
Var. x Spacing	@5%	n.s.	n.s.	n.s.	n.s.
	@1%	n.s.	n.s.	n.s.	n.s.

In 1950 when plants of the Maryland Golden variety were set at distances of 10, 15, and 20 inches, no effect was observed upon the yield, the grade, the average weight, or the number of storage roots as may be seen in Tables 9, 10, 11, and 12.

C. Method of Propagation.

An experiment was conducted in 1949 to compare the two common methods for propagating sweet potatoes, namely, sprouts and vine cuttings. Two dates of planting were chosen, May 21 and June 21. Since it was not possible in the early planting to obtain true vine cuttings, sprouts with the entire root system cut off were used. The results obtained (6) indicated that there was no difference between the two methods as affecting the total yield or the grade of potatoes. It is further shown in Tables 13 and 14 that the method of propagation did not affect the number or the average weight of the storage roots. It was found that at each of the two planting dates, the cutting method resulted in a higher percentage of cracking as compared to the sprout method.

D. Vine Pruning.

An experiment was conducted in 1950 to determine the effect of reducing the top:root ratio in the sweet potato plant with respect to yield and the size of the storage roots. Maryland Golden sprouts were planted on May 25. As one treatment the vines were cut back to approximately 10 inches on July 15, while in a second treatment the plants were pruned on August 15, to compare the effects of early and late pruning. A third plot was left untreated to serve as a check.

Table 9. Analysis of Variance of the Effect of Hill Spacing on Yield, Grade and Number of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Source	D/F	Variance	
		Yield	Number
Spacing	2	162.7	1384.5
Replicate	2	186.6	5645.0
Error (a)	4	110.6	1060.0
Total	8		
Grade	2	4576.0**	187713.5**
Spacing x Grade	4	166.7	2404.8
Error (b)	12	76.6	1495.5
Total	26		

**Significant at odds of 99:1

Table 10. Analysis of Variance of the Effect of Hill Spacing on the Size of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Source	D/F	Variance
		Ave. Wt./Root
Spacing	2	0.0016
Replicate	2	0.0001
Error	4	0.0004
Total	8	

Table 11. Effect of Hill Spacing on Yield, Grade, and Size of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Spacing	Yield Bu./A. Jumbo	Market	Canning	Total	Ave. Wt./Root Lb.
20"	12.0	112.9	90.6	218.5	0.17
15"	9.1	140.8	83.2	233.1	0.21
10"	15.8	188.5	84.5	288.8	0.21
L.S.D. @ 5%		n.s.		n.s.	n.s.

Table 12. Effect of Hill Spacing on the Number of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Spacing	Number of Roots/300' Row Jumbo	Market	Canning	Total
20"	8	299	979	1286
15"	6	333	785	1124
10"	12	476	850	1338
L.S.D. @ 5%		n.s.		n.s.

Table 13. Analysis of Variance of the Effect of Method of Propagation on Number of Storage Roots, Size of Storage Roots, and Cracking of Maryland Golden Sweet Potatoes. (1949)

Source	D/F	Variance		
		Number	Ave. Wt.	% Cracking
Method	1	60	0.0001	473.06*
Date	1	7876**	0.0676**	73.96
Replicate	3	1007	0.0078	43.33
Method x Date	1	1139	0.0000	37.74
Error	9	316	0.0032	70.86
Total	15			

*Significant at odds of 19:1
**Significant at odds of 99:1

Table 14. Effect of Method of Propagation on Yield, Number of Storage Roots, Size of Storage Roots, and Cracking of Maryland Golden Sweet Potatoes. (1949)

Date 1949	Method	Yield Bu./A.	Number Roots/300' Row	Ave. Wt./Root Lb.	% Cracked
May 21	Sprouts	292.8	828	0.36	28.5
	Cuttings	246.8	704	0.35	41.0
	Average	269.8	767	0.36	34.7
June 21	Sprouts	95.6	461	0.23	18.2
	Cuttings	120.4	539	0.22	39.3
	Average	105.9	500	0.23	28.7
Average	Sprouts	191.8	645	0.30	23.4
	Cuttings	183.3	621	0.29	40.2
L. S. D.					
Method	@ 5%	n.s.	n.s.	n.s.	14.7
	@ 1%	n.s.	n.s.	n.s.	n.s.
Date	@ 5%	50.2	122	0.06	n.s.
	@ 1%	67.2	174	0.09	n.s.
Method x Date	@ 5%	n.s.	n.s.	n.s.	n.s.
	@ 1%	n.s.	n.s.	n.s.	n.s.

Data obtained at harvest are presented in Tables 15, 16, 17, and 18, and indicate that the total yield was not affected by pruning. The grade of the storage roots was affected by pruning, however, and the late treatment exhibited a stronger effect than the early treatment. The average weight of the storage roots from the late pruning treatment was smaller than the check, while the early treatment showed no difference. The check and the early pruned plots produced higher yields of the market grade than of the canning grade, whereas the late pruned plots produced equal yields of market and canning grade. Furthermore, the yield of the jumbo grade was remarkably reduced by vine pruning with the late pruning showing more effect than the early pruning. With regard to number of storage roots (Table 18) it was again found that although the total number of storage roots per row was not affected, the number of storage roots within each grade was significantly influenced. Again late pruning was more effective than early pruning, and increased the number of potatoes of the canning grade. Also, the number of jumbo potatoes was reduced, while the number of the market grade potatoes was not affected.

Table 15. Analysis of Variance of the Effect of Vine Pruning on Yield, Grade, and Number of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Source	D/F	Variance Yield	Variance Number
Treatment	2	272.5	1421.0
Replicate	2	219.5	2847.0
Error (a)	4	109.2	926.0
Total	8		
Grade	2	19237.8**	150140.5**
Treatment x Grade	4	830.2**	7371.3**
Error (b)	12	132.9	1328.8
Total	26		

**Significant at odds of 99:1

Table 16. Analysis of Variance of the Effect of Vine Pruning on the Size of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Source	D/F	Variance Ave. Wt./Root
Treatment	2	0.0115*
Replicate	2	0.0019
Error	4	0.0015
Total	8	

*Significant at odds of 19:1

Table 17. Effect of Vine Pruning on Yield, Grade, and Size of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Treatment	Yield Bu./A. Jumbo	Market	Canning	Total	Ave. Wt./Root Lb.
Check	34.1	334.8	72.9	441.8	0.36
Pruned July 15	12.5	314.7	86.9	414.1	0.31
Pruned Aug. 15	1.4	210.0	134.2	345.6	0.24
L.S.D. @ 5%		87.1		n.s.	0.09
L.S.D. @ 1%		122.2		n.s.	n.s.

Table 18. Effect of Vine Pruning on Number of Storage Roots of Maryland Golden Sweet Potatoes. (1950)

Treatment	Number of Roots/300' Row Jumbo	Market	Canning	Total
Check	22	673	551	1246
Pruned July 15	9	670	687	1366
Pruned Aug. 15	1	522	949	1472
L.S.D. @ 5%		275.3		n.s.
L.S.D. @ 1%		386.5		n.s.

II. STUDIES OF GROWTH

The data obtained in 1949 indicated that the variety and the date of planting were the two main factors affecting the percentage of cracking in sweet potatoes. In that year Maryland Golden and Jersey Orange varieties were planted on each of five successive dates at two-week intervals, beginning on May 6. When harvested on October 8, percentage of cracking was much higher in Maryland Golden than in Jersey Orange and the first and fourth dates of planting resulted in a higher percentage of cracking than any of the other three dates.

In 1950 field experiments were designed to determine the effect of variety and date of planting on the growth of the storage roots. Sprouts of Maryland Golden and Jersey Orange varieties were planted on each of four successive dates at two-week intervals beginning on May 11. In addition to these two varieties, Porto Rico, Allgold, B-5999, L-241, and Australian Canner were planted on May 25. Sampling was started 6 weeks after planting and continued at two-week intervals until September 21, except for a three-week interval between the last two samplings.

Sampling was randomized in triplicate within each variety, with each sample composed of ten adjacent plants. All storage roots were counted and weighed from which the yield per plant, the number of storage roots per plant, and the average weight per storage root were calculated.

A. Phenological Observations as Related to Growth.

Since the occurrence and severity of cracking varies from year to year, and the possibility of association with climate exists (11), a study of the weather conditions during 1949 and 1950 was made. A comparison of these two seasons are of particular interest since heavy losses from cracking occurred in 1949 whereas no significant cracking was observed in the following year.

In Table 19 and Figure 1, the growing seasons are divided into ten two-week periods starting with the earliest plantings on May 6 and May 11 in 1949 and 1950, respectively. The mean temperature and the accumulated precipitation for each period are presented. In general, the temperature was higher in 1949 than in 1950 during most of the season. In 1949 two drought periods accompanied by very high temperatures occurred during the fourth and sixth periods of the season, corresponding to late June and late July. Only one drought period occurred in 1950, during the seventh and eighth periods of the season, with only 0.18 inch of rain accumulated between August 7 and September 1. The mean temperature in 1949 decreased steadily after the sixth period until harvest. Compared to 1949, the mean temperature in 1950 was relatively constant for the greater part of the season and did not start to decrease except after the ninth period.

B. Effect of Date of Planting on Growth.

Maryland Golden and Jersey Orange sweet potatoes were planted in 1950 on four successive dates at two-week intervals. Samplings were also made at two-week intervals beginning 6 weeks after planting. The data presented in Table 20 and Figure 2 show the weight of storage roots

Table 19. Average Mean Temperature and Precipitation for Each of Ten Two-Week Periods Beginning May 6 and May 11 in 1949 and 1950 Respectively.

	1949*			1950		
Period	Date	Mean Temperature	Precipitation	Date	Mean Temperature	Precipitation
1.	May 6 - May 19	66.3	0.74	May 11 - May 24	61.2	3.96
2.	May 20 - June 2	63.8	2.86	May 25 - June 7	66.7	1.11
3.	June 3 - June 16	73.2	1.26	June 8 - June 21	70.5	1.27
4.	June 17 - June 30	80.1	0.07	June 22 - July 5	76.3	2.13
5.	July 1 - July 14	77.7	1.74	July 6 - July 19	75.6	2.53
6.	July 15 - July 28	83.4	0.37	July 20 - Aug. 2	76.6	2.82
7.	July 29 - Aug. 11	78.8	1.65	Aug. 3 - Aug. 16	73.5	0.90
8.	Aug. 12 - Aug. 25	73.3	4.17	Aug. 17 - Aug. 30	75.4	0.14
9.	Aug. 26 - Sept. 8	70.5	2.59	Aug. 31 - Sept. 13	73.8	2.25
10.	Sept. 9 - Sept. 22	61.7	1.19	Sept. 14 - Sept. 27	62.5	3.02

*Temperature and precipitation for 1949 were obtained from the official records of the U. S. Department of Commerce (Climatological Data), while the temperature and rainfall in 1950 were measured at the Vegetable Research Farm at Salisbury.

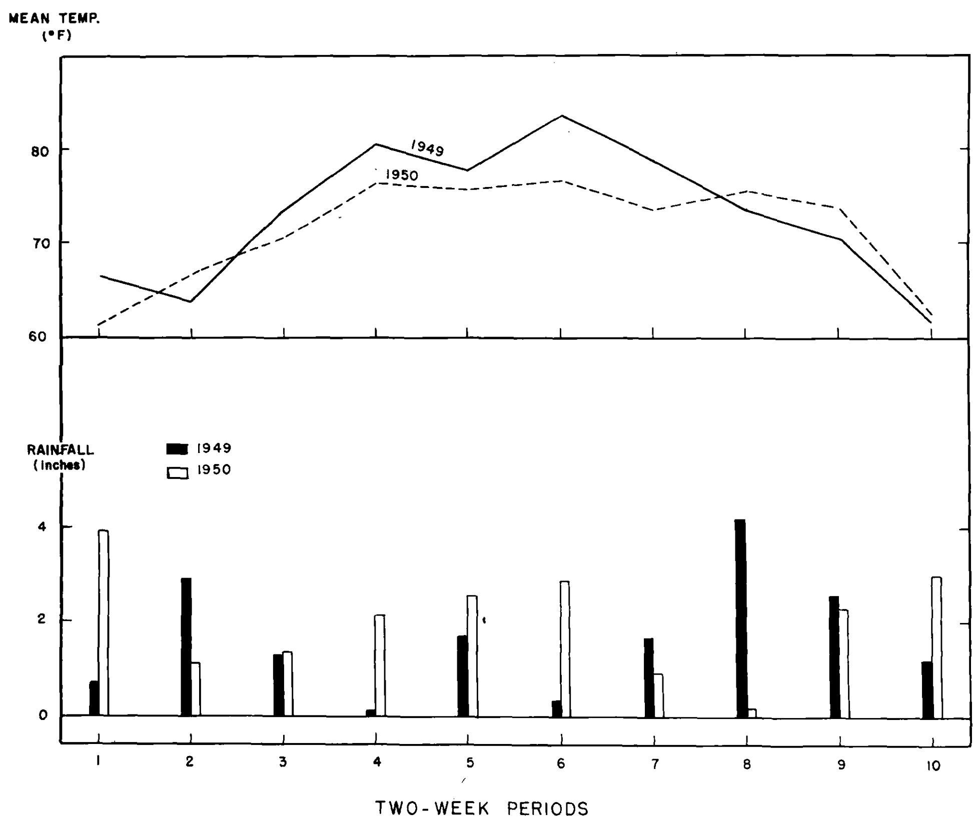

Figure 1. Mean temperature and precipitation for each of ten two-week periods beginning May 6 in 1949 and May 11 in 1950.

Table 20. Average Yield of Storage Roots per Plant in Grams of Maryland Golden and Jersey Orange Varieties Planted at four Successive Dates and Harvested at Two-Week Intervals Starting Six Weeks After Planting.

Planting Date	Date of Harvest						
	June 22	July 6	July 20	Aug. 3	Aug. 17	Aug. 31	Sept. [illegible]
				Maryland Golden			
May 11	0.4 ± 0.2	5.3 ± 1.2	44.2 ± 16.1	117.3 ± 16.2	321.5 ± 58.3	457.8 ± 26.8	861.5 ± 123.8
May 25		4.3 ± 1.0	20.0 ± 4.0	61.2 ± 30.3	179.7 ± 31.3	380.2 ± 116.0	626.1 ± 77.7
June 8			9.8 ± 0.4	65.6 ± 17.5	211.6 ± 104.8	[illegible]	513.0 ± 35.4
June 22				9.9 ± 1.3	39.[illegible] ± 9.3	121.1 ± 62.6	238.3 ± 49.6
				Jersey Orange			
May 11	0.9 ± 0.7	7.4 ± 2.7	38.9 ± 10.4	128.6 ± 13.3	342.4 ± 40.2	518.3 ± 66.5	728.3 ± 134.4
May 25		5.3 ± 1.2	34.0 ± 8.6	90.7 ± 6.8	242.2 ± 29.2	450.2 ± 34.6	673.4 ± 154.0
June 8			18.4 ± 6.1	88.2 ± 30.6	196.7 ± 69.3	368.0 ± 40.1	563.7 ± 33.8
June 22				13.1 ± 3.6	51.1 ± 11.3	113.5 ± 39.6	261.0 ± 113.4

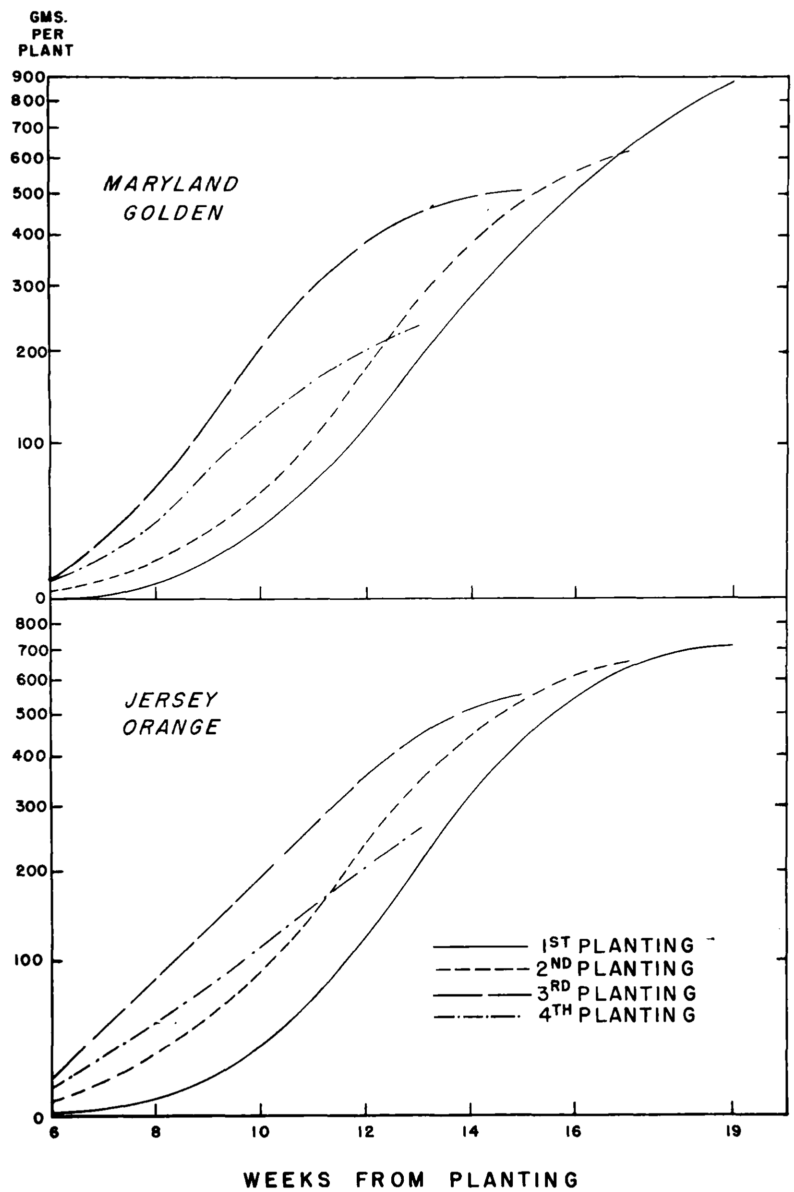

Figure 2. Average yield of storage roots per plant of Maryland Golden and Jersey Orange varieties planted at four successive dates and harvested at two-week intervals starting six weeks after planting.

per plant throughout the growing season. Semi-log paper is used in presenting the growth curves, since it is suggested by Sinnot (32) that this is most suitable for presenting growth curves when the initial values are very minute as compared to the final values. Table 20 shows that in both varieties the final yield per plant was considerably decreased with the delay in planting. In Figure 2 the yield per plant is plotted against the age of the plant and shows that the delay in planting actually resulted in acceleration in the rate of growth as measured by yield of storage roots per plant. This was true in both varieties through the third planting, decreasing with the fourth planting date. This indicates that the length of the growing season is not the only factor responsible for the effect of planting dates on final yields of sweet potatoes.

When studying the effect of a certain factor on the yield of the sweet potato plant, two main aspects were considered: the effect of such a factor on the size or the weight of the storage roots, and on the number of the storage roots. Table 21 shows the effect of the date of planting on the cumulative increase in the average weight per storage root of Maryland Golden and Jersey Orange varieties throughout the growing season. In Figure 3 the same data are plotted against the age of the plants and indicate that the rate of growth was accelerated with the delay in planting, reaching a maximum with the third date of planting and decreasing again with the fourth date. This proved to be true in both varieties when the growth rates (<u>k</u> values) were determined from Robertson's (28) formula: $\log \frac{x}{A - x} = \underline{k}\,(t - t_1)$ where x = the weight of the root at time t, A = the final value of x, t_1 = the time

Table 21. Average Weight per Storage Root in Grams of Maryland Golden and Jersey Orange Varieties Planted at Four Successive Dates and Harvested at Two-Week Intervals Starting Six Weeks After Planting.

Planting Date	Date of Harvest						
	June 22	July 6	July 20	Aug. 3	Aug. 17	Aug. 31	Sept. 21
				Maryland Golden			
May 11	1.3 ± 1.1	3.4 ± 1.6	9.6 ± 2.3	23.8 ± 0.4	57.9 ± 17.2	68.6 ± 7.1	161.3 ± 15.7
May 25		1.5 ± 0.6	7.2 ± 5.6	12.1 ± 5.6	31.4 ± 4.6	58.3 ± 3.7	110.1 ± 8.1
June 8			2.0 ± 1.1	17.6 ± 0.7	34.4 ± 6.1	56.7 ± 19.9	75.4 ± 14.0
June 22				3.1 ± 0.4	7.9 ± 2.3	22.6 ± 6.4	48.5 ± 19.6
				Jersey Orange			
May 11	0.6 ± 0.1	2.7 ± 0.4	8.1 ± 2.4	20.8 ± 2.3	44.9 ± 3.7	67.9 ± 17.3	109.5 ± 16.5
May 25		12. ± 0.3	6.0 ± 1.2	13.0 ± 1.3	33.8 ± 2.8	51.9 ± 14.3	86.9 ± 4.1
June 8			2.6 ± 0.4	11.3 ± 3.4	22.4 ± 0.5	40.0 ± 4.9	60.0 ± 13.7
June 22				2.8 ± 0.8	7.5 ± 1.3	16.5 ± 10.2	30.2 ± 10.0

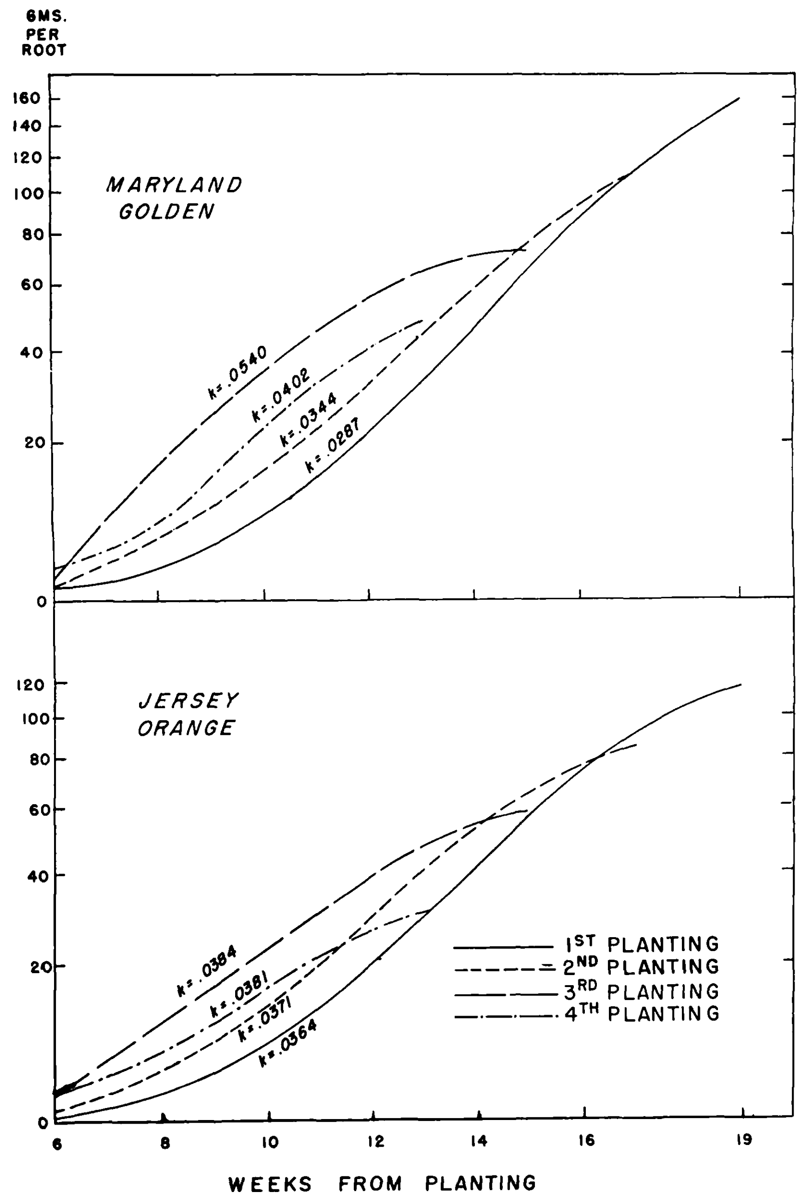

Figure 3. The average weight per storage root of Maryland Golden and Jersey Orange varieties planted at four successive dates and harvested at two-week intervals starting six weeks after planting.

when the value of x becomes equal to $\frac{A}{2}$, and k = the growth rate. Values of k for each growth curve are given in Figure 3. Although the data in Figure 3 are plotted on semi-log paper, the values for k were calculated from growth curves where the actual weights were plotted against the actual age of the plants. The k values indicate that the effect of the time of planting on the growth rate of the storage roots was greater with Maryland Golden than with Jersey Orange. Comparing k values for the two varieties it may be seen that in the first two plantings Jersey Orange had a higher growth rate than Maryland Golden, while in the third and fourth plantings the reverse was true. It is observed that the acceleration of the growth rate due to the delay in planting was never high enough to compensate for the difference in the lengths of the growing seasons, and in both varieties the final average weight per root was definitely decreased with the delay in planting.

Since the delay in planting was found to accelerate the growth of the storage root, it would be interesting to determine the relationship between temperature and the growth of the sweet potato storage root. This was done by correlating the weight of the root at each harvest with the accumulated heat units above certain base lines. Base lines of 70, 65, 60, 55, 50, 45, and 40 degrees F. were used, and the summations of day-degrees between the date of planting and each harvest date were determined. These data are presented in Table 22. Summations of day-degrees were then correlated with the square root of the average weight per storage root (Table 23), and the correlation

Table 22. Summations of Day-Degrees Accumulated Between Planting Dates and Successive Harvests in 1950.

Planting Date	Base Line	Date of Harvest						
		June 22	July 6	July 20	Aug. 3	Aug 17	Aug. 31	Sept. 21
May 11	70°F	37	126	204	297	349	425	488
May 25			125	203	296	348	424	487
June 8				200	293	346	422	485
June 22					259	312	388	451
May 11	65°F	124	282	430	593	712	858	985
May 25			276	426	589	709	855	981
June 8				393	556	675	821	948
June 22					469	588	734	861
May 11	60°F	273	501	719	952	1141	1357	1584
May 25			469	687	920	1109	1325	1552
June 8				593	826	1015	1231	1458
June 22					679	868	1084	1311
May 11	55°F	473	771	1059	1362	1621	1907	2204
May 25			679	967	1270	1529	1815	2112
June 8				803	1106	1365	1651	1948
June 22					889	1148	1434	1731
May 11	50°F	678	1046	1404	1777	2106	2462	2829
May 25			889	1247	1620	1949	2305	2652
June 8				1013	1386	1715	2071	2418
June 22					1099	1428	1784	2131
May 11	45°F	888	1326	1754	2197	2596	3022	3459
May 25			1099	1527	1970	2369	2795	3232
June 8				1223	1668	2065	2491	2928
June 22					1309	1708	2134	2571
May 11	40°F	1098	1606	2104	2617	3086	3582	4089
May 25			1309	1807	2320	2789	3285	3792
June 8				1433	1944	2415	2911	3418
June 22					1517	1988	2484	2991

Table 23. Square Roots of the Average Weight per Storage Root of Maryland Golden and Jersey Orange Sweet Potatoes Planted on Four Successive Dates and Harvested at Two-Week Intervals Beginning Six Weeks After Planting.

Variety	Planting Date	Date of Harvest						
		June 22	July 6	July 20	Aug. 3	Aug. 17	Aug. 31	Sept. 21
Maryland Golden	May 11	1.1	1.8	3.1	4.9	7.6	8.3	12.7
	May 25		1.2	2.7	3.5	5.6	7.6	10.5
	June 8			1.4	4.2	5.8	7.5	8.7
	June 22				1.7	2.8	4.8	7.0
Jersey Orange	May 11	0.8	1.6	2.8	4.6	6.7	8.2	10.5
	May 25		1.1	2.4	3.6	5.8	7.2	9.3
	June 8			1.6	3.3	4.7	6.3	7.7
	June 22				1.7	2.7	4.0	5.5

coefficients are given in Table 24. This method of correlating heat unit summations with growth for the determination of appropriate base lines was first suggested by Stark (34). The most suitable base line would be that temperature which results in the highest correlation coefficient when the remainder heat units are correlated with growth. The data presented in Table 24 show that in both varieties, the values of *r* increased as the base line decreased as indicated by the use of the *z* test (33). It is also indicated that base lines of 45°F. and 50°F. may be considered most suitable for Maryland Golden and Jersey Orange varieties respectively.

The data relating to the effect of date of planting on the number of storage roots per plant are presented in Table 25. It may be observed that, in general, the number of storage roots per plant increases for a time and then remains constant until the end of the season. The rate of increase in the number of the storage roots and the time required for the attainment of the final number are evidently affected by the date of planting. With Maryland Golden no significant increase in number of storage roots was found after July 20 (10 weeks) for the first planting, after August 3 (10 weeks) for the second planting, August 17 (10 weeks) for the third planting, and August 17 (8 weeks) for the fourth planting. In Jersey Orange no significance in number of roots was observed after August 17 (14 weeks) for the first planting, August 3 (10 weeks) for the second planting, July 20 (6 weeks) for the third planting, and August 17 (8 weeks) for the fourth planting. It is interesting to note that the effect of the date of planting on the rate of increase in the number of storage roots is very similar to its effect on the increase in the weight of the storage roots. The

Table 24. Coefficients of Correlation and z Values for Summations of Day-Degrees Accumulated above Different Base-Lines and the Square Roots of the Average Weight per Storage Root of Maryland Golden and Jersey Orange Sweet Potatoes Planted on May 11, May 25, June 8, and June 22, and Harvested at Two-Week Intervals Beginning Six Weeks After Planting.

	Maryland Golden		Jersey Orange	
Base Line	r	z	r	z
70° F.	0.880	1.38	0.883	1.40
65° F.	0.945	1.79	0.951	1.84
60° F.	0.954	1.87	0.960	1.95
55° F.	0.963	1.98	0.972	2.11
50° F.	0.973	2.16	0.985	2.45
45° F.	0.975	2.19	0.988	2.55
40° F.	0.975	2.19	0.989	2.59

Difference required for significance between any two z values = 0.32

Table 25. Average Number of Storage Roots per Plant of Maryland Golden and Jersey Orange Sweet Potatoes Planted at Four Successive Dates and Harvested at Two-Week Intervals Starting Six Weeks After Planting.

Planting Date	Date of Harvest						
	June 22	July 6	July 20	Aug. 3	Aug. 17	Aug. 31	Sept. 21
				Maryland Golden			
May 11	0.5 ± 0.4	1.8 ± 0.6	5.0 ± 3.0	5.0 ± 0.9	5.7 ± 1.2	6.7 ± 0.9	5.8 ± 1.3
May 25		2.9 ± 0.9	3.5 ± 1.6	5.1 ± 1.1	5.8 ± 0.7	6.5 ± 1.6	5.7 ± 0.8
June 8			5.3 ± 1.6	3.9 ± 1.0	6.2 ± 3.0	7.1 ± 1.3	6.8 ± 1.7
June 22				3.3 ± 0.8	5.1 ± 1.0	5.4 ± 2.1	6.2 ± 1.3
				Jersey Orange			
May 11	1.5 ± 0.6	2.7 ± 0.4	4.8 ± 0.5	6.2 ± 0.4	7.5 ± 0.6	8.0 ± 2.3	6.6 ± 0.6
May 25		4.5 ± 0.8	5.6 ± 0.6	7.0 ± 0.6	7.2 ± 0.3	9.1 ± 2.1	7.7 ± 1.0
June 8			7.0 ± 1.6	7.8 ± 1.5	8.6 ± 1.4	9.2 ± 1.5	9.7 ± 2.1
June 22				4.6 ± 0.5	6.8 ± 0.8	7.5 ± 1.8	8.5 ± 1.2

attainment of the final number of storage roots was accelerated by the delay in planting until the third planting, and was slower again in the fourth planting.

Cracking of vine potatoes. Maryland Golden and Jersey Orange varieties produce storage roots on the adventitious roots developing at the nodes of the vines. These vine potatoes were first observed in 1950 at the August 31 sampling. Although no significant cracking occurred in 1950, 34.5 per cent of these vine potatoes were found to be cracked in Maryland Golden and 13.5 per cent in Jersey Orange. It is interesting to observe that these vine potatoes were initiated during the only drought period of the season, which prevailed from August 7 to September 1.

C. Effect of Variety on Growth.

Five varieties in addition to Maryland Golden and Jersey Orange, were planted on May 25. Data were obtained on yield per plant, average weight per storage root, and number of storage roots per plant throughout the growing season of 1950. In Table 26 and Figure 4, data on yield per plant are given, and indicate that the rate of increase in yield differed with the variety. Compared to the other varieties, Allgold had the highest yield per plant at the first four samplings and then slowed down throughout the duration of the season. Australian Canner gave comparatively low yields during the first five harvests followed by an increase in yield during the last three weeks of the season. Maryland Golden, Jersey Orange, and B-5999 behaved more or less similarly, with Jersey Orange giving the highest yields. Porto Rico and L-241 showed close resemblance, the former giving higher yields

Table 26. Average Yield per Plant in Grams of Seven Varieties of Sweet Potatoes Planted on May 25 and Harvested at Six Successive Dates Starting Six Weeks After Planting.

Variety	Period from Planting to Harvest					
	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	17 weeks
Maryland Golden	4.3 ± 1.0	20.0 ± 4.0	61.5 ± 30.0	179.7 ± 31.3	380.2 ± 116.0	626.1 ± 77.7
Jersey Orange	5.3 ± 1.2	34.0 ± 8.6	90.7 ± 6.8	242.2 ± 29.2	450.2 ± 34.6	673.4 ± 154.0
Porto Rico	3.1 ± 0.5	18.6 ± 7.9	71.9 ± 7.0	189.2 ± 54.2	357.6 ± 133.4	510.7 ± 46.8
Allgold	16.9 ± 8.9	54.5 ± 12.4	115.4 ± 13.1	281.8 ± 63.9	372.7 ± 42.7	554.2 ± 32.8
B-5999	3.0 ± 0.6	23.6 ± 11.3	28.3 ± 9.9	206.2 ± 116.6	289.4 ± 31.9	578.8 ± 128.8
L-241	2.8 ± 2.2	15.0 ± 8.1	63.0 ± 11.8	191.7 ± 44.3	411.1 ± 113.2	575.1 ± 134.3
Australian Canner	1.9 ± 1.4	13.6 ± 0.5	55.4 ± 8.9	158.9 ± 13.4	264.8 ± 43.3	635.6 ± 243.5

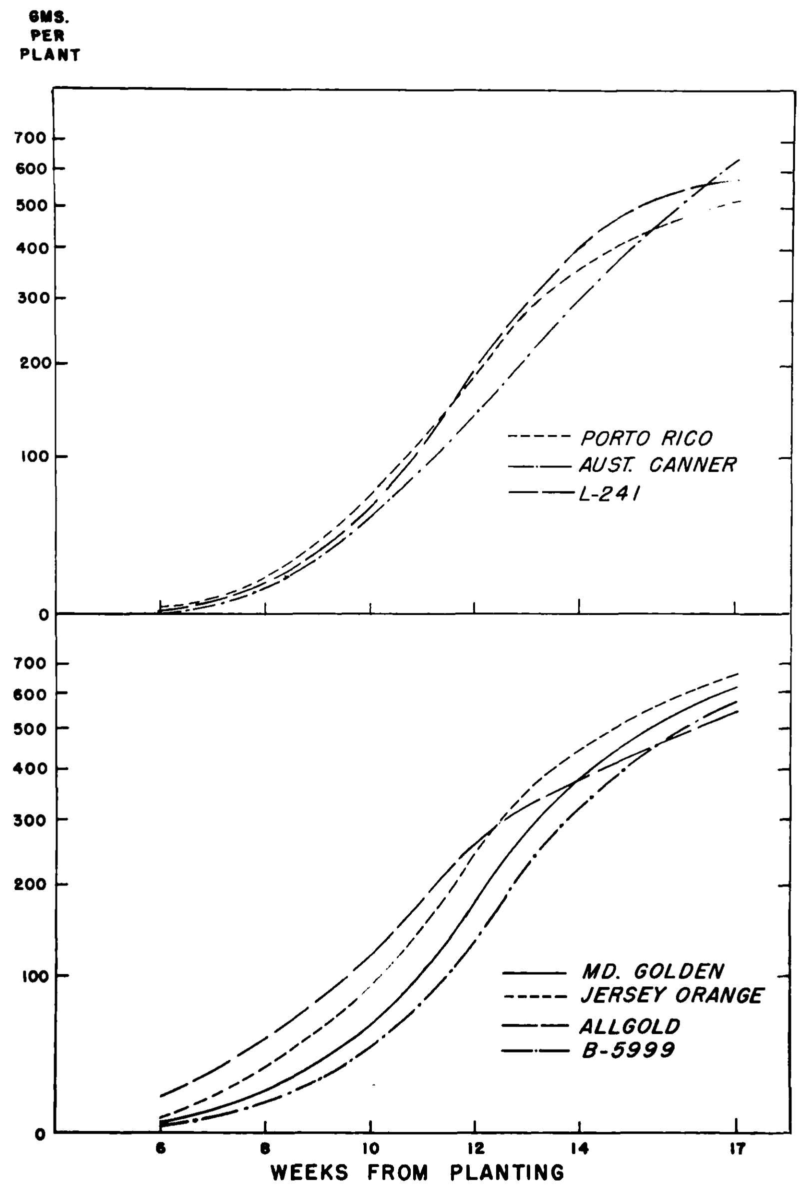

Figure 4. Average yield of storage roots per plant of seven sweet potato varieties planted on May 25 and harvested at six successive dates starting six weeks after planting.

during the first three harvests after which L-241 began to show a greater rate of increase surpassing Porto Rico and ending the season with a higher yield.

Varietal differences in yield are due to difference in the size and number of the storage roots. Table 27 and Figure 5 present the cumulative increase in the average weight per storage root in each of the seven varieties, previously mentioned. It may be seen that All-gold again had the largest roots for the first three harvests, then its rate of growth decreased during the remainder of the season. The six other varieties fall into two groups; the first includes Maryland Golden, Jersey Orange, and B-5999, and the second group includes Porto Rico, L-241, and Australian Canner. In the first group the average weight per root increases steadily through the season, while in the second group the weight per root increased rapidly during the middle of the season then more slowly towards the end of the season. The difference between these two groups may be seen in Table 28 and Figure 6 which present the increase in the average weight per storage root at each of the six harvests. In the second group, including Porto Rico, L-241 and Australian Canner, the gain in the weight of the root dropped sharply after the fifth harvest, while the gain in weight increases steadily in the other group. In the first group B-5999 has the largest roots followed by Maryland Golden while Jersey Orange has the smallest. A difference between the average root weights of Maryland Golden and Jersey Orange was found to exist only during the last two harvests, reflecting a more rapid rate of increase in Maryland Golden than Jersey Orange at the end of the season. The varieties of the second group show close similarity to each other in their growth be-

[redacted]

Table 27. Average Weight per Storage Root in Grams of Seven Varieties Planted on May 25 and Harvested at Six Successive Dates Starting Six Weeks after Planting.

Variety	Period from Planting to Harvest					
	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	17 weeks
Maryland Golden	1.5 ± 0.6	7.2 ± 5.6	12.1 ± 5.6	31.4 ± 4.6	58.3 ± 3.7	110.1 ± 8.1
Jersey Orange	1.2 ± 0.3	6.0 ± 1.2	13.0 ± 1.3	33.8 ± 2.8	51.9 ± 14.3	86.9 ± 4.1
Porto Rico	1.8 ± 0.1	5.6 ± 2.3	17.8 ± 4.2	40.6 ± 7.2	94.9 ± 23.6	123.1 ± 31.8
Allgold	4.2 ± 1.9	9.9 ± 2.5	21.6 ± 3.1	38.1 ± 9.2	60.2 ± 16.2	91.1 ± 13.1
B-5999	1.8 ± 0.1	8.7 ± 3.5	16.6 ± 3.9	73.1 ± 23.6	82.5 ± 22.2	177.8 ± 57.6
L-241	1.3 ± 0.8	3.9 ± 1.3	14.8 ± 2.9	28.9 ± 8.8	70.5 ± 19.4	82.2 ± 11.4
Australian Canner	1.5 ± 0.8	5.6 ± 0.9	12.4 ± 1.7	30.6 ± 1.4	81.7 ± 36.5	101.1 ± 32.5

[redacted]

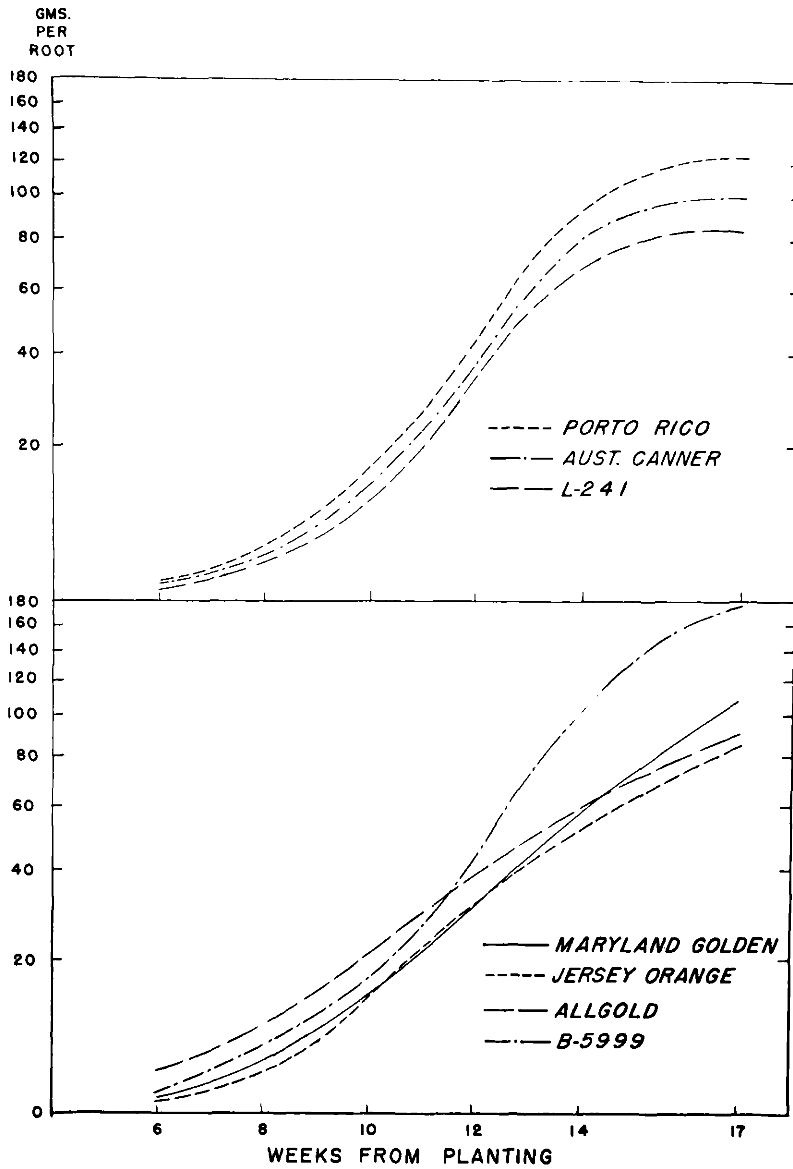

Figure 5. Average weight per storage root of seven sweet potato varieties planted on May 25 and harvested at six successive dates starting six weeks after planting.

Table 28. Increase in the Weight per Storage Root (Grams) of Each of Seven Varieties Planted May 25 and Harvested at Six Successive Dates Starting Six Weeks after Planting.

Variety	Period from Planting to Harvest					
	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	17 weeks
Maryland Golden	1.5	5.7	4.9	19.3	26.9	51.9
Jersey Orange	1.2	4.8	7.0	20.8	18.1	35.0
Porto Rico	1.8	3.8	12.2	22.8	54.3	28.2
Allgold	4.2	5.7	11.7	16.5	22.1	30.9
B-5999	1.8	6.9	7.9	56.5	9.4	95.3
L-241	1.3	2.6	10.9	14.1	41.6	11.7
Australian Canner	1.5	4.1	6.8	18.2	51.1	19.4

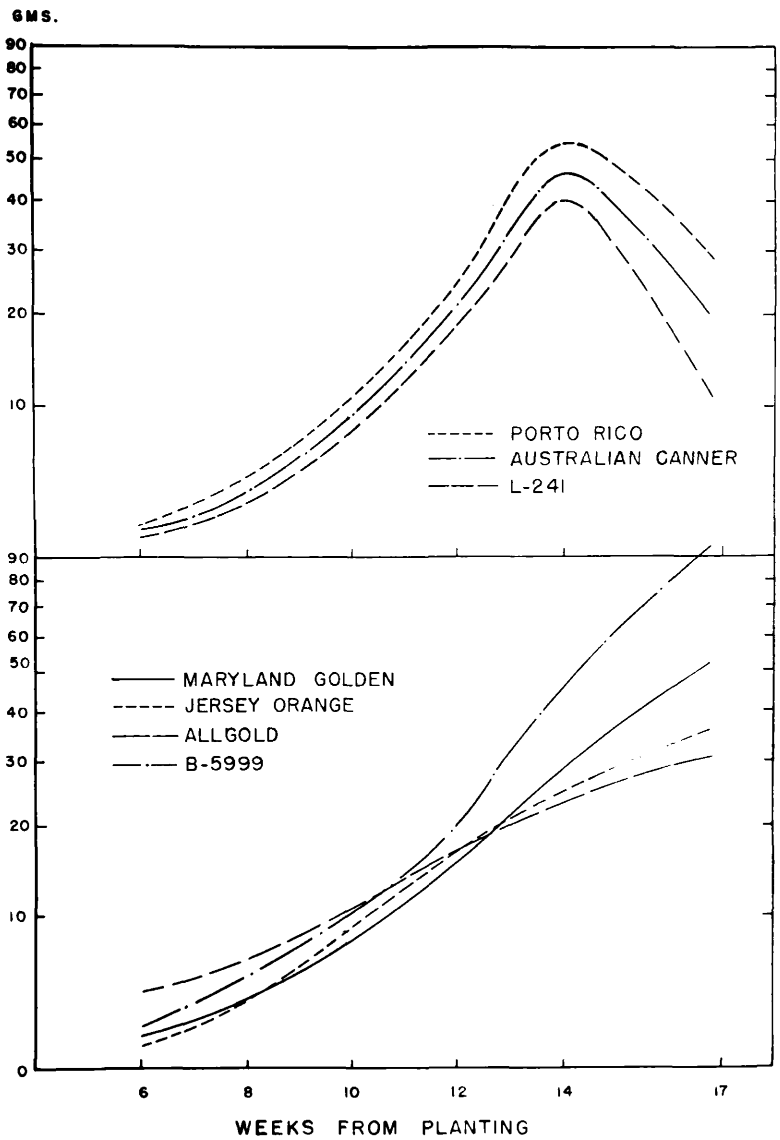

Figure 6. Increase in the weight per storage root during two-week periods of seven sweet potato varieties planted on May 25 and harvested at six successive dates starting six weeks after planting.

havior, with Porto Rico giving the largest roots, L-241 the smallest, and Australian Canner intermediate.

With regard to the number of storage roots per plant (Table 29), it is interesting to note that there is a negative correlation of - 0.9269 between the size of the roots and the number of roots. Varieties producing the largest storage roots (Table 27) have the least number of roots per plant (Table 29), and vice versa. On basis of number of roots per plant, the different varieties are in the following descending order: Jersey Orange, L-241, Australian Canner, Allgold, Maryland Golden, Porto Rico, and B-5999. The time required for attainment of the final number of roots differed with the variety. Maryland Golden, Jersey Orange, Porto Rico, and Australian Canner require 10 weeks from planting. Allgold again shows earliness in root formation and only 8 weeks are required whereas B-5999 and L-241 are comparatively slow and require 12 weeks for attainment of final number of roots.

Table 29. Average Number of Storage Roots per Plant of Seven Varieties Planted on May 25 and Harvested at Six Successive Dates Starting Six Weeks after Planting.

Variety	Period from Planting to Harvest					
	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	17 weeks
Maryland Golden	2.9 ± 0.9	3.5 ± 1.6	5.1 ± 1.1	5.8 ± 0.7	6.5 ± 1.6	5.7 ± 0.8
Jersey Orange	4.5 ± 0.8	5.6 ± 0.6	7.0 ± 0.6	7.2 ± 0.3	9.1 ± 2.1	7.7 ± 1.0
Porto Rico	1.7 ± 0.4	3.5 ± 0.7	4.2 ± 1.1	4.5 ± 1.7	3.7 ± 0.7	4.4 ± 1.3
Allgold	3.9 ± 0.9	5.6 ± 0.5	5.4 ± 0.7	7.5 ± 1.3	6.3 ± 1.0	6.2 ± 1.5
B-5999	1.7 ± 0.4	2.7 ± 0.5	1.7 ± 0.3	2.8 ± 1.3	3.7 ± 0.9	3.3 ± 0.4
L-241	2.2 ± 1.6	3.8 ± 1.3	4.3 ± 0.2	6.8 ± 1.2	5.8 ± 0.0	6.9 ± 1.0
Australian Canner	1.1 + 0.5	2.4 + 0.4	4.5 + 0.8	5.2 + 0.7	3.7 + 1.7	6.3 + 2.1

III. HISTOLOGICAL AND MICROENVIRONMENT STUDIES

Studies were undertaken in an effort to associate varietal differences in the incidence of cracking with histological differences among those varieties and to describe the tissue changes that result from cracking of the storage root, as well as the cellular activity concomitant to healing of the ruptured tissues. Tissue activity of root slices was determined in a microenvironment as an adjunct of findings on cracking and healing of the cracked roots.

Beginning on June 22 and until September 21, samples of storage roots of Maryland Golden and Jersey Orange were collected at two-week intervals including normal roots free of damage, and roots exhibiting different stages of cracking and healing. The samples were stored in formalin-acetic acid-alcohol killing and fixing solution. "Tissuemat" was used for embedding, and a Safranin O-Fast Green FCF staining schedule was employed.

A. Observations on Cracking.

Microscopic examinations of the storage roots indicate that growth cracks may start as internal rupture of the tissues outside the vascular cylinder (Figure 7). It is conjectured that such rupture is due to the pressure exerted by the enlarging vascular cylinder on comparatively inactive outer tissues. Inactivity of the outer tissues probably results from unfavorable environmental conditions, and cracking results as a release of this internal pressure. The severity of cracking depends on the relative inactivity of the outer tissues.

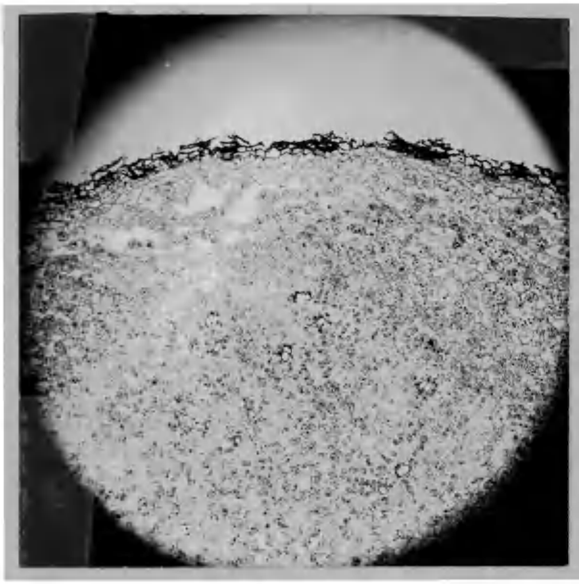

Figure 7. Dissociation of cortex in a young storage root.

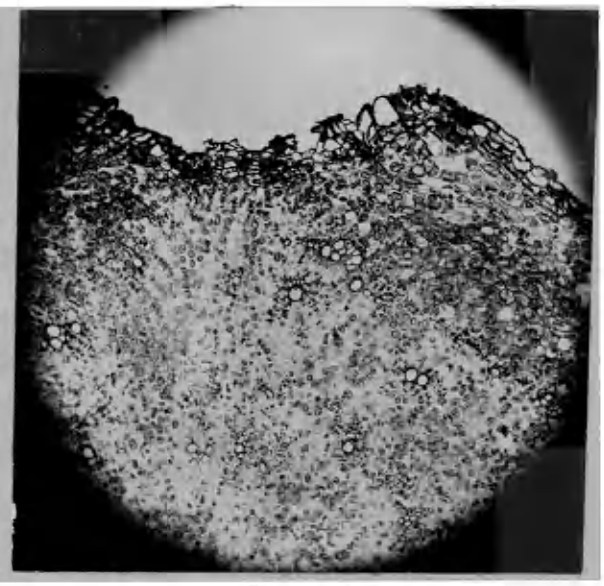

Figure 8. A shallow crack in cortex of a young storage root.

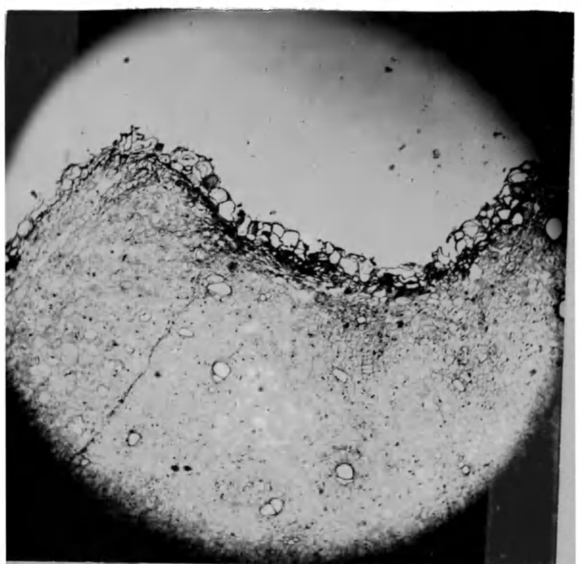

Figure 9. A crack penetrating the cambial ring in a young storage root.

Growth cracks may be shallow and limited to the tissues outside the vascular cylinder (Figure 8) or they may be deep and penetrate the cambial ring (Figure 9). Suberization takes place in the exposed outer cells, and a secondary cambium originates in the tissues subtending the exposed cells forming wound tissues (Figure 10). Under conditions favoring formation of wound tissues, growth cracks may be rapidly healed (Figure 11), provided there is sufficient time for healing before harvest. When cracking and healing takes place early in the season, the cleavage becomes shallower as the root develops (Figure 12), the surface finally becoming almost normal. The external appearance of the root shown in Figure 13 was normal except for a slight scar. However, the cross section shows a non-continuous cambial ring which indicates the occurrence of cracking during the early stages of development.

B. Tissue Activity Studies in Microenvironment.

U. S. No. 1 storage roots from the final harvest of Maryland Golden and Jersey Orange were cut into slices 1/4 inch in thickness. Four slices from the center portion of each root were selected and the slices from all roots of each variety were mixed together. Units of four slices were picked at random and placed in dessicators on a false bottom of plastic screening. Each dessicator contained 8 slices, 4 of each variety. The dessicators were placed in storage rooms at 85° and 50° F. Humidity within the dessicators was kept at a high relative humidity by the addition of water below the false bottom and in the vent, or at a low relative humidity by the substitution of calcium chloride for the water. Both humidity and temperature within

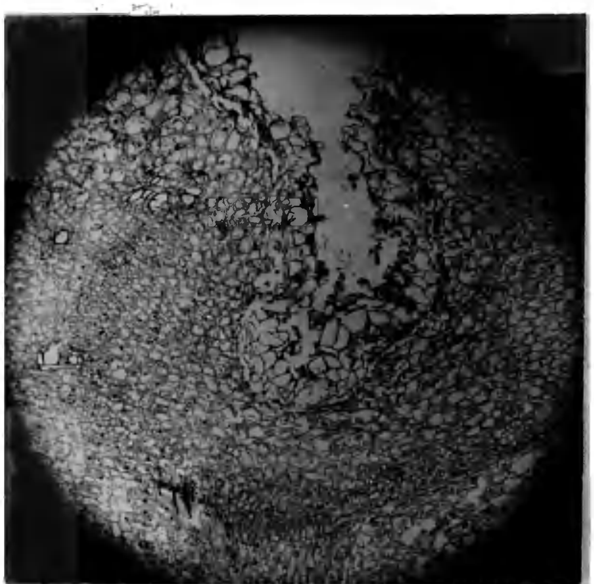

Figure 10. Meristematic activity around a deep crack and formation of healing tissues.

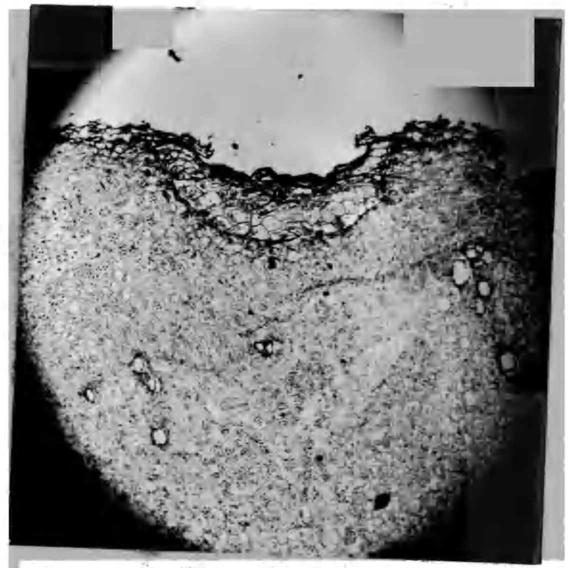

Figure 11. Healing of a shallow crack.

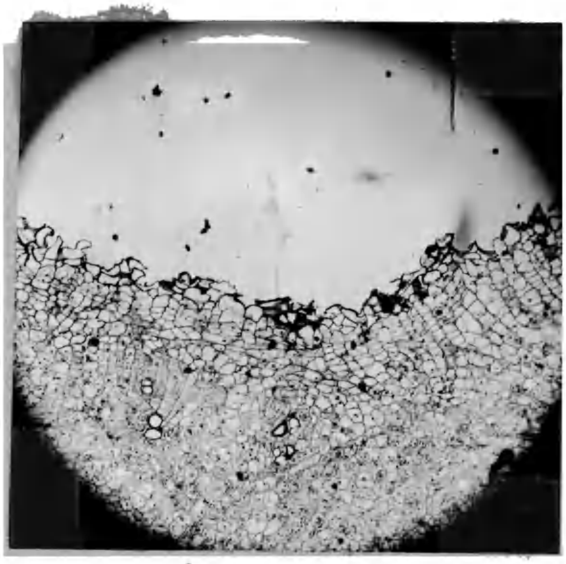

Figure 12. Expansion of a healed crack.

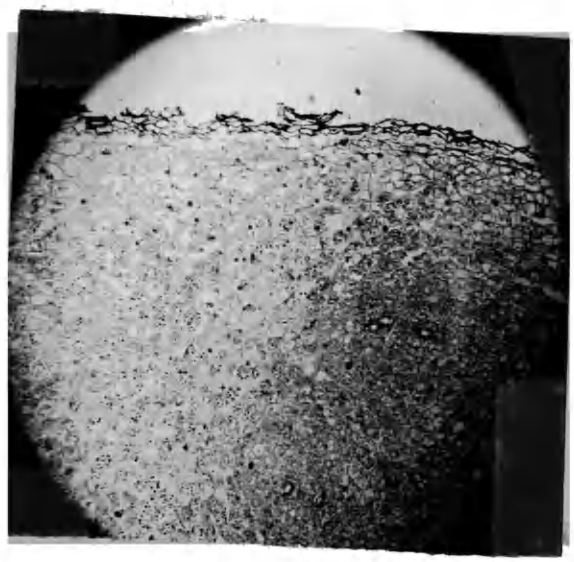

Figure 13. A completely healed storage root showing a discontinuous cambial ring.

the chambers were frequently checked with an Airguide, Jr.[1] installed inside the dessicators. A drawing of the apparatus is shown in Figure 14. The length of the microenvironment treatment was five days, after which the slices were examined, and samples were taken for histological studies, and treated as above.

The external appearance of root sections stored for 5 days in microenvironment chambers indicate that tissue activity is affected by temperature, moisture, and variety of sweet potato (Figure 15). Tissue activity was measured by the development of wound tissue proliferation at the surface of the root sections. At a temperature of 50° F., no wound tissue was observed regardless of the moisture level. At 85° F., more wound tissue was formed under moist conditions than under relatively dry conditions. Jersey Orange showed greater proliferation than did Maryland Golden.

Microscopic examination of longisections of the slices indicates that the proliferations formed by Jersey Orange are larger than those formed by Maryland Golden (compare Figures 16 and 19). It is also observed that the proliferations are a product of the secondary cambium units (Figure 19). At 85° F. with moist conditions, Jersey Orange had a layer of wound tissue of 5-8 cell thickness (Figure 20), while Maryland Golden had a layer of 3-4 cell thickness (Figure 17). At the same temperature with low relative humidity, a wound tissue layer of 2-4 cell thickness was observed in Jersey Orange (Figure 21) whereas no wound tissue was found in Maryland Golden (Figure 18), indicating the relative inactivity of the tissues of Maryland Golden under conditions of low humidity.

---

[1] Manufactured by Central Scientific Company, New York.

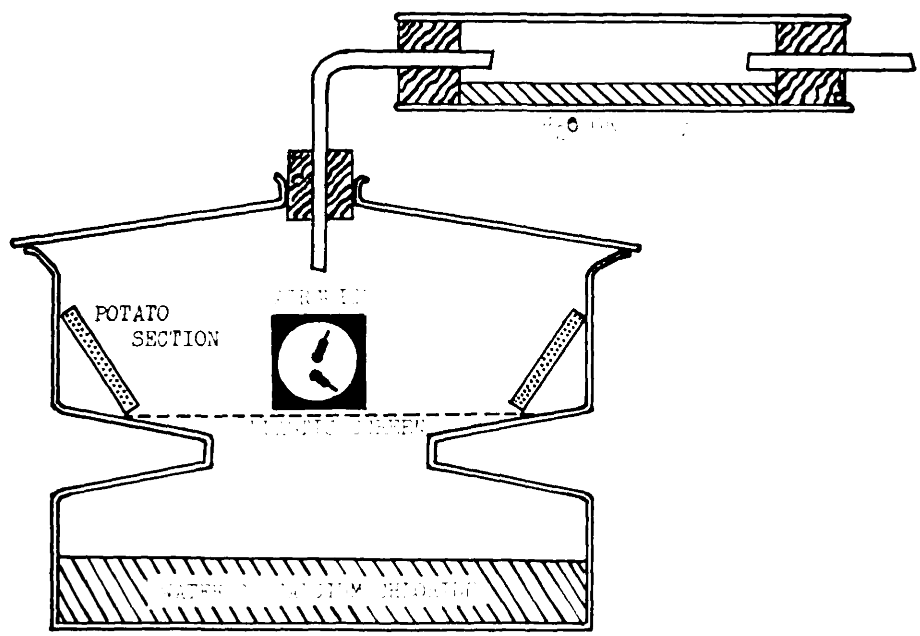

Figure 14. Apparatus used in tissue activity experiments.

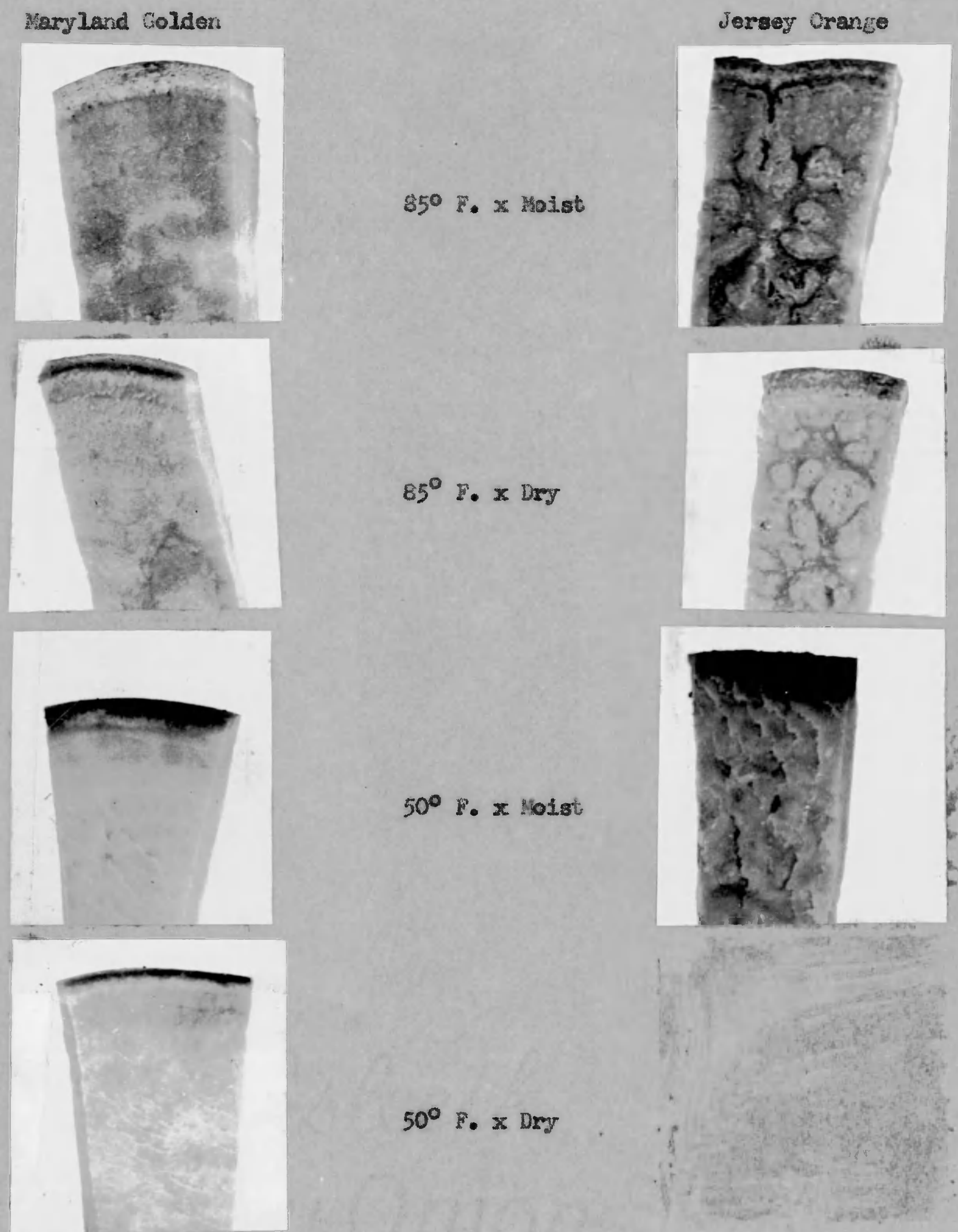

Figure 15. External appearance of Maryland Golden and Jersey Orange tissues showing various degrees of proliferation when subjected to different levels of temperature and humidity.

LEGEND FOR FIGURES 16 TO 21

Figure 16. Proliferation in Maryland Golden tissues at 85° F. and high relative humidity. Figure 17. Wound tissue formation (above arrow) in Maryland Golden at 85° F. and high relative humidity. Figure 18. Absence of wound tissues in Maryland Golden at 85° F. and low relative humidity. Figure 19. Proliferation in Jersey Orange tissues at 85° F. and high relative humidity. Figure 20. Wound tissue formation (above arrow) in Jersey Orange at 85° F. and high relative humidity. Figure 21. Wound tissue formation (above arrow) in Jersey Orange at 85° F. and low relative humidity.

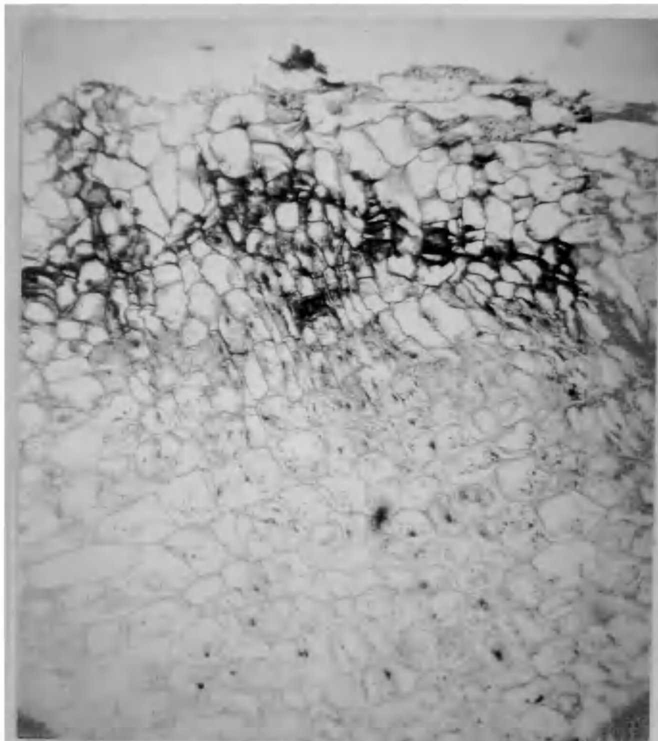

Figure 16

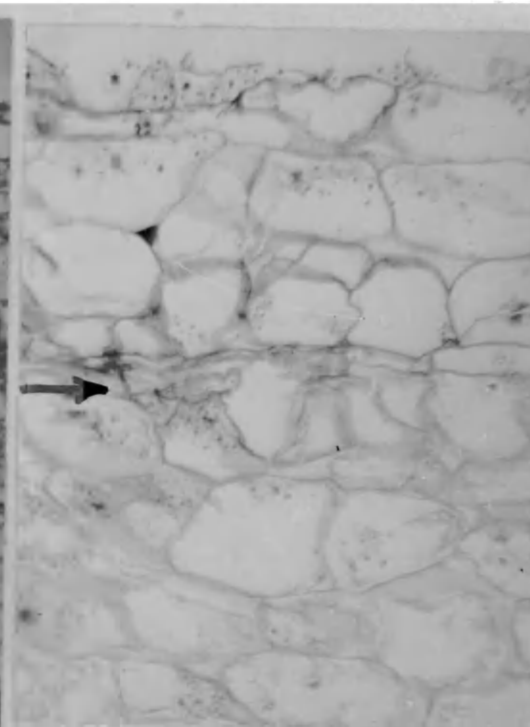

Figure 17

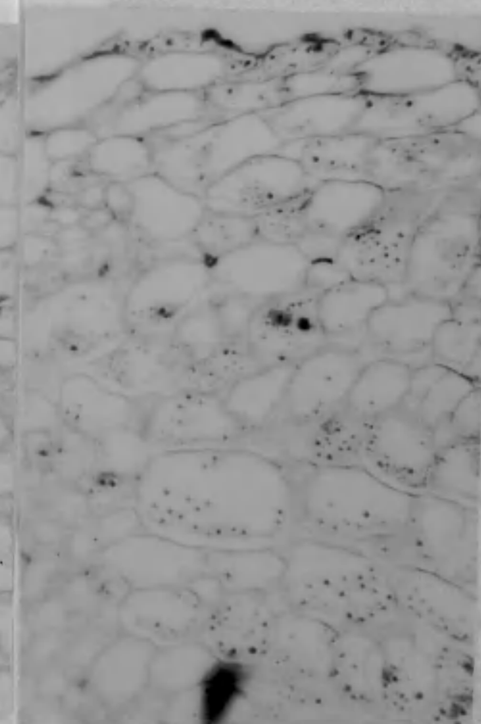

Figure 18

Maryland Golden

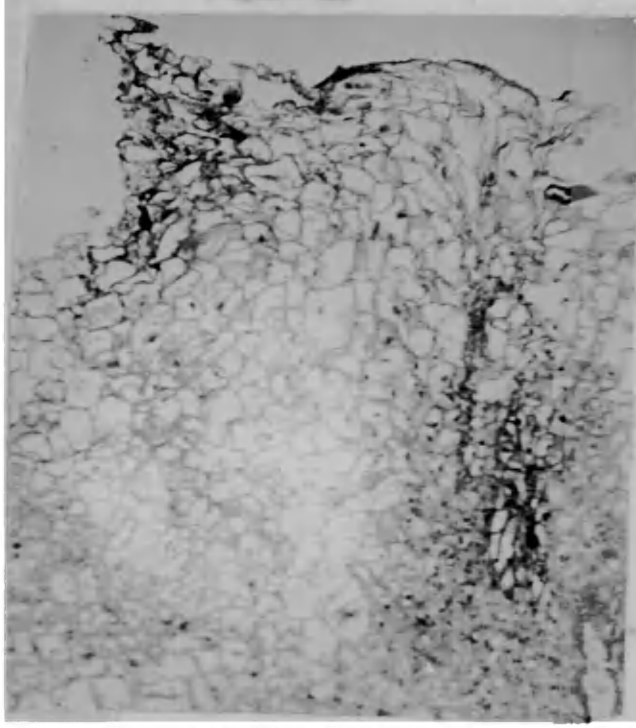

Figure 19

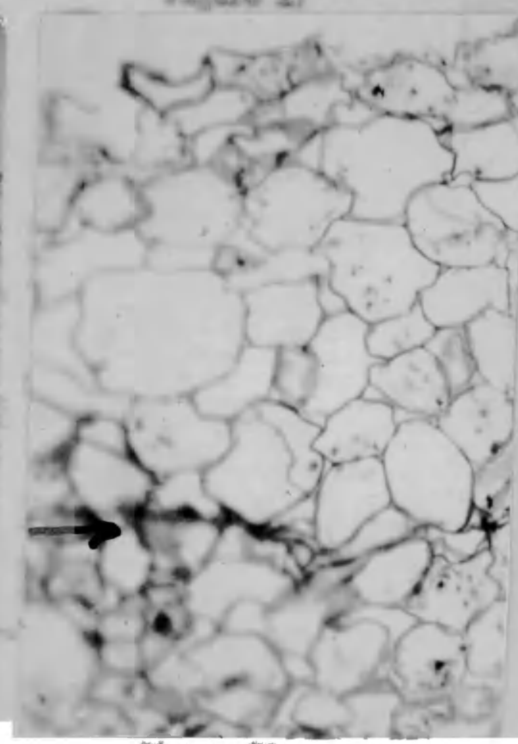

Figure 20

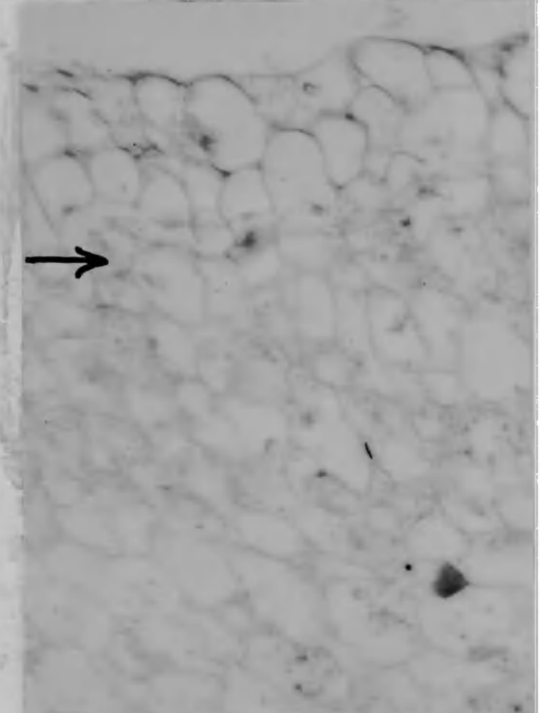

Figure 21

Jersey Orange

C. Varietal Differences in Structure.

Storage roots of Maryland Golden and Jersey Orange varieties were collected at different stages of development ranging from 3 mm. to 5 cm. in diameter approximately. Microscopic examination indicates that these two varieties differ in the anatomical structure of their storage roots. From examination of cross sections of young fleshy roots, it was found that the Jersey Orange variety has more xylem vessels than does Maryland Golden and that the vessels in Jersey Orange are smaller in size, as shown in Figure 22. As the root develops, the expansion of the vascular cylinder and the increase in production of pericyclic parenchyma pushes the endodermis and cortex outwards (16). Failure of the cortex to keep pace with the expansion of the vascular cylinder results in crushing of the cortex cells, as illustrated in Figure 23. The greater number of crushed areas in the cortex of Maryland Golden as compared with Jersey Orange, indicates either a slower rate of elongation and division of the cortex parenchyma cells, or a faster rate of growth of the axis, resulting in greater internal pressure on the cortex in Maryland Golden.

In mature sweet potato fleshy roots (16), the epidermis, the cortex, the endodermis are no longer present. A pericyclic periderm is maintained by an active phellogen throughout the growth period of the root and forms the protective "skin." The area within the periderm is composed of large pericyclic parenchymatous cells and phloem elements. In a comparison of mature fleshy roots of the two varieties, Jersey Orange has a more uniform pericyclic parenchyma than Maryland Golden (Figure 24). The pericyclic parenchyma in Maryland Golden is

LEGEND FOR FIGURES 22 TO 24

Figure 22. Cross sections in young storage roots (3 mm. diam.) of Maryland Golden and Jersey Orange varieties. Figure 23. Cross sections in young storage roots (6 mm. diam.) of Maryland Golden and Jersey Orange varieties showing development of pericyclic parenchyma. Figure 24. Cross sections in mature storage roots of Maryland Golden and Jersey Orange varieties.

Maryland Golden   Jersey Orange

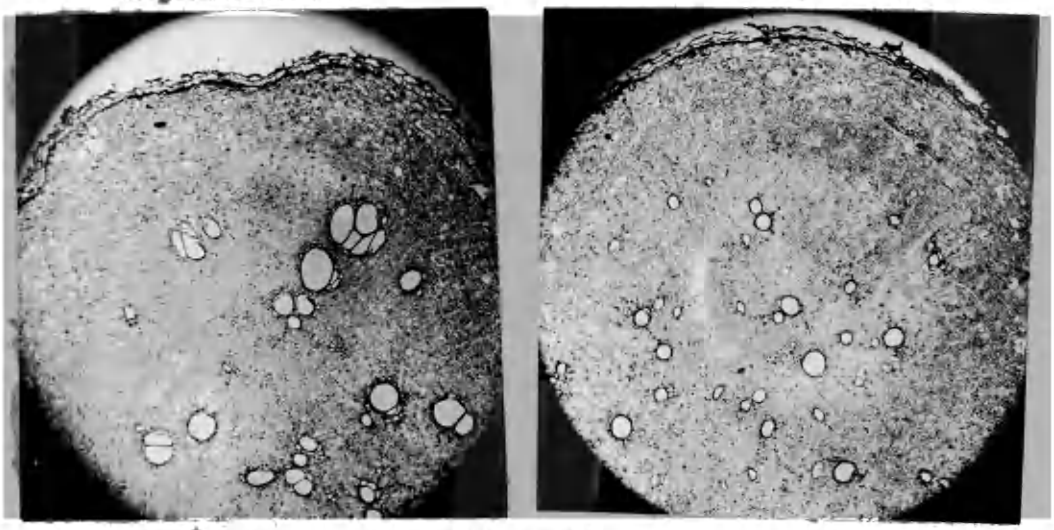

Figure 22

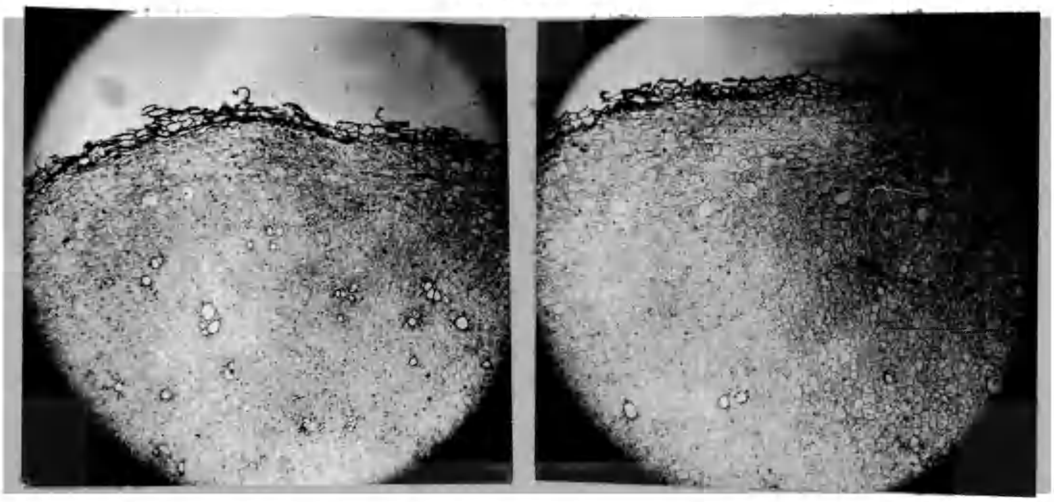

Figure 23

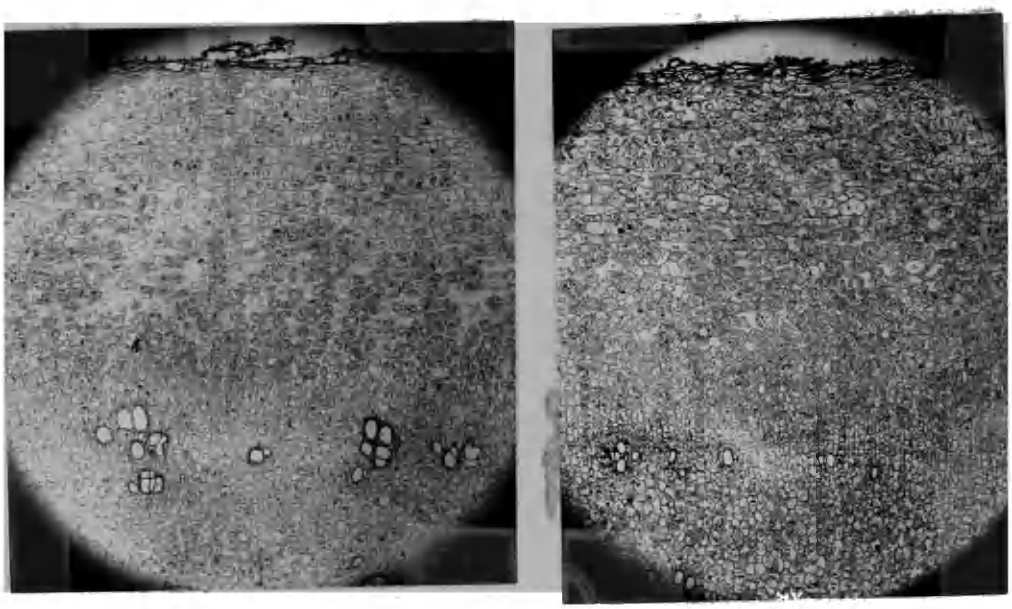

Figure 24

interrupted by irregular areas which are distinguishable from the surrounding tissues by their lighter color and may meet Artschwager's (1) description of the interstitial parenchyma. Examination of cross sections of both varieties indicates that Jersey Orange has a cambial ring of 4-6 cells in thickness while the cambial ring in Maryland Golden was only 2-3 cells in thickness (Figure 25). The secondary cambiums are more abundant in Jersey Orange, and the xylem vessels are smaller and surrounded by more secondary cambium in comparison with Maryland Golden as may be seen in Figures 26 and 27 respectively.

LEGEND FOR FIGURES 25 TO 27

Figure 25. Cambial rings in mature storage roots of Maryland Golden and Jersey Orange varieties. Figure 26. Secondary cambium units in mature storage roots of Maryland Golden and Jersey Orange varieties. Figure 27. Secondary cambium originating in the xylem parenchyma of Maryland Golden and Jersey Orange storage roots.

Maryland Golden   Jersey Orange

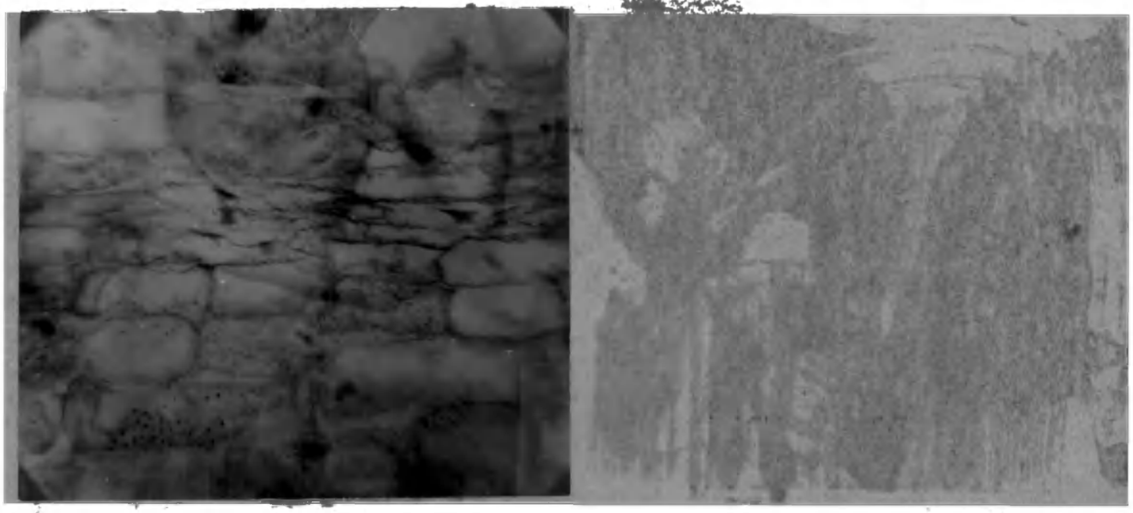

Figure 25

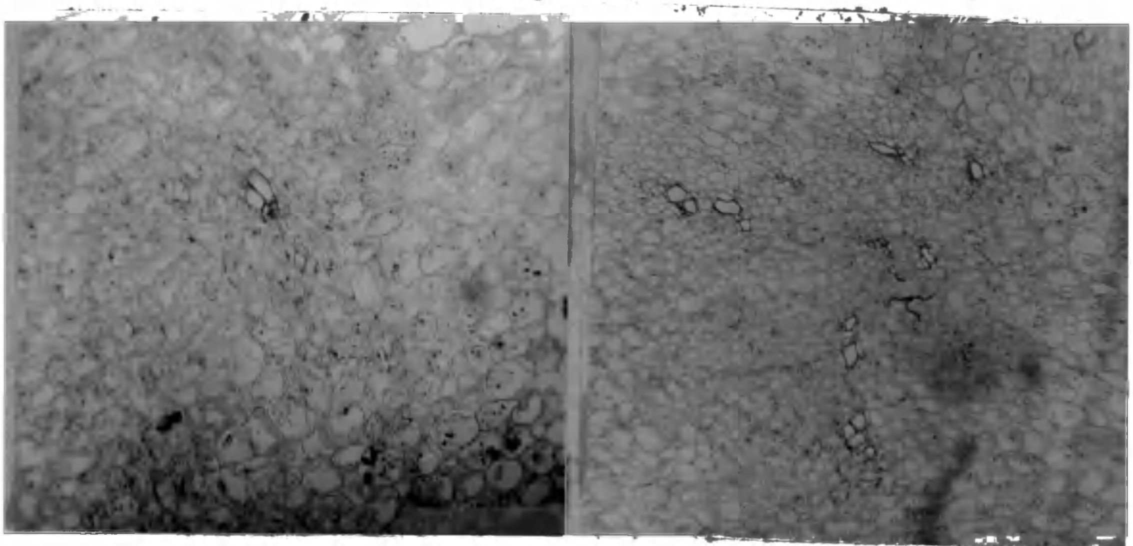

Figure 26

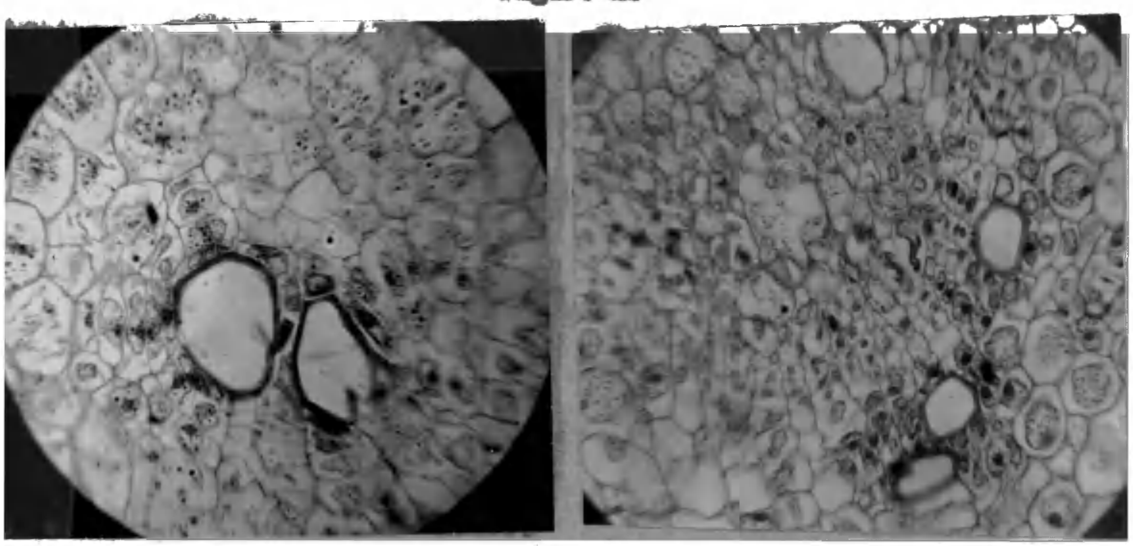

Figure 27

IV. STUDIES OF MOISTURE RELATIONS WITHIN THE PLANT

Moisture could be one of the important seasonal variables involved in the cracking phenomenon. Very little is known about the moisture relations that exist within the sweet potato plant, or the different factors that would affect such relations. In this present study two main phases of moisture were studied, namely the moisture content and the water uptake by the tissues. The latter was expressed as per cent water uptake by the tissues to show the relative affinity of such tissues to water.

For determining the total moisture content, longitudinal slices were taken from five storage roots, chopped up, and a composite sample of 100 gms. was placed in a Waring Blender with 200 ml. of tap water and blended for five minutes. Samples were taken from the homogeneous blend and placed in an 80° F. oven for 24 hours, weighed, and the moisture percentage was calculated. Water uptake by the tissues of the storage roots was determined by making transverse slices of 1-1/2 inches in thickness through the center portion of the storage roots, and longitudinal cores were secured from these slices by using a sharp cork borer (1/2 inch diam.). The cores were cut to uniform length of one inch, a five core sample was weighed, and was immediately immersed in water in a beaker. The beakers were then placed at 40° F. temperature to retard any enzymatic hydrolysis that might occur in the tissues of the storage roots. After 24 hours, the cores were removed from the water, blotted gently with absorbent tissue paper and weighed. The percentage water uptake was determined to express the relative affinity of the tissues to water.

Vine samples were taken for determination of the water uptake with each sample being composed of a 10 cm. section from the central portion of five vines chosen at random. Vines were collected from the field always at sunset, all leaves and petioles were clipped off and the 10 cm. portions of the vines were secured by the use of a sharp razor blade. The five portions were then weighed and placed vertically in a beaker with their basal end immersed in water. The beakers were left at room temperature for 24 hours. After that period they were removed from water, blotted gently with tissue paper, and weighed again. The water uptake percentage was calculated on a fresh weight basis.

A. Effect of Variety.

The storage roots of the market grade of Maryland Golden, Jersey Orange, Porto Rico, Allgold, B-5999, L-241, and Australian Canner, obtained from the final harvest, were compared in regard to their total moisture percentage and their capacity of water uptake. The results obtained (Table 30) indicate that Allgold, B-5999, and L-241 varieties were highest in moisture content, Jersey Orange and Porto Rico were intermediate, and Maryland Golden and Australian Canner were lowest. It was found that Maryland Golden and Jersey Orange exhibited a much higher water uptake than the other varieties with Maryland Golden having a higher affinity to water than Jersey Orange. Porto Rico, B-5999 and Allgold were intermediate and L-241 and Australian Canner were low. Comparison of the water uptake of the storage roots of these varieties with their moisture content, shows that the variation in moisture content does not explain the variation in affinity of the tissues to water. It may be concluded that the total moisture determination in the storage

Table 30. Total Moisture and Water Uptake of the Storage Roots of Seven Varieties of Sweet Potatoes.

Variety	Total Moisture %	Water Uptake %
Maryland Golden	72.80	24.24
Jersey Orange	73.93	21.54
Porto Rico	73.14	14.57
Allgold	75.47	13.71
B-5999	75.80	14.01
L-241	75.16	11.37
Australian Canner	71.44	11.34
Mean	73.96	15.83
F Value	517.00**	43.60**
L.S.D. @ 5%	0.21	2.27

**Significant at odds of 99:1

roots is not a reliable test for predicting the ability of the root tissues to absorb water.

The water uptake of the vines of the seven varieties was determined at two dates. The first sampling was 10 weeks after planting and was during a dry period. The second sampling was 16 weeks after planting and was during a wet period. Obviously the effect of environment was confounded with the age of plants since the plants during the dry period were younger than during the wet period. The results obtained are presented in Table 31 and indicate that the water uptake of the vines was affected by the variety. Based on the average of the two periods, Jersey Orange and B-5999 exhibited the highest water uptake, Porto Rico, Allgold, and Australian Canner were intermediate, and Maryland Golden and L-241 were lowest. All varieties except Maryland Golden and Jersey Orange exhibited higher water uptake during the dry period than during the wet period. Maryland Golden and Jersey Orange did not show any difference between the two periods.

B. Effect of Age of Plants on the Water Uptake of the Vines.

Maryland Golden and Jersey Orange varieties were planted at four successive dates: May 11, May 25, June 8, and June 22. The vines of both varieties were sampled for determination of water uptake throughout the development of the plants. After six weeks from planting, sampling started and continued at two-week intervals until the end of the growing season. The complete data are given in Table 32. On the basis of averages for all dates of planting, it may be observed that in both varieties the water uptake of the vines decreased as the plants grew older. The decrease in the water uptake of the vines of Maryland

Table 31. Water Uptake by the Vines of Seven Sweet Potato Varieties Sampled Ten and Sixteen Weeks After Planting.

Variety	Percentage of Water Uptake		
	10 weeks	16 weeks	Mean
Maryland Golden	15.0	16.2	15.6
Jersey Orange	24.0	22.6	23.3
Porto Rico	22.0	15.1	18.5
Allgold	23.0	11.8	17.4
B-5999	24.4	16.5	20.5
L-241	15.5	10.9	13.2
Australian Canner	20.0	13.5	16.7
Mean	20.6	15.2	17.9

	F Value	L.S.D. @ 5%
Variety	106.3**	2.1
Period	23.4**	1.0
Variety x Period	9.3*	2.9

* Significant at odds of 19:1
**Significant at odds of 99:1

Table 32. Effect of Age of Plants on the Water Uptake of the Vines of Maryland Golden and Jersey Orange Varieties Planted at Four Successive Dates.

Age	Date of Planting				Mean
	May 11	May 25	June 8	July 22	
		Maryland Golden			
6 weeks	26.3 ± 1.3	18.7 ± 9.2	25.8 ± 0.4	30.5 ± 6.0	25.3
8 weeks	13.9 ± 1.2	24.7 ± 5.5	23.0 ± 3.3	19.8 ± 3.2	20.6
10 weeks	13.6 ± 3.5	15.0 ± 1.0	12.0 ± 1.3	18.9 ± 2.8	14.9
12 weeks	17.7 ± 1.4	15.7 ± 1.7	13.4 ± 1.1	14.3 ± 1.3	15.3
14 weeks	22.3 ± 0.6	14.2 ± 1.0	19.5 ± 4.7		18.7
16 weeks	17.7 ± 2.3	16.2 ± 1.5			17.0
18 weeks	15.3 ± 0.9				15.3
		Jersey Orange			
6 weeks	21.6 ± 4.4	25.3 ± 13.9	21.3 ± 3.4	37.4 ± 3.9	26.4
8 weeks	16.6 ± 2.1	24.0 ± 7.2	39.7 ± 2.3	22.7 ± 2.1	25.8
10 weeks	21.7 ± 1.7	24.0 ± 2.7	20.8 ± 3.4	20.6 ± 0.8	21.8
12 weeks	22.3 ± 2.3	22.7 ± 2.8	31.9 ± 0.8	17.0 ± 0.7	23.5
14 weeks	21.7 ± 4.5	21.1 ± 2.8	16.6 ± 1.4		19.8
16 weeks	19.7 ± 0.2	22.6 ± 2.5			21.1
18 weeks	17.3 + 2.2				17.3

Golden occurred very rapidly while the decrease was gradual in Jersey Orange. At all stages of development the vines of Jersey Orange exhibited greater affinity to water than Maryland Golden.

C. Effect of the Size of the Storage Roots.

Storage roots of the jumbo, market, and canning grades of both Maryland Golden and Jersey Orange varieties were used to determine the difference in the moisture content and water uptake of the different sizes of storage roots. The results shown in Table 33, indicate that in both varieties, the storage roots of the jumbo grade are higher in moisture content than the storage roots of either the market or the canning grades. There was no difference in the moisture content of the latter two grades. Also, no difference in moisture content was found between the two varieties.

Water uptake was found to be affected by both variety and grade. The data presented in Table 33 indicate that in both varieties the canning grade exhibited the highest affinity to water, followed by the jumbo grade, and the market grade was the lowest. Within each grade the storage roots of Maryland Golden showed a higher water uptake than the storage roots of Jersey Orange. It may be seen in Table 33 that although there is no varietal difference in total moisture, there is a large difference in water uptake. Furthermore, storage roots of the canning grade exhibit a higher water uptake than the market grade while no difference was observed between the moisture content of the two grades. These results indicate that, again, the moisture content of the storage roots does not explain their affinity to water.

Table 33. Effect of the Size of Roots on the Total Moisture and Water Uptake in Maryland Golden and Jersey Orange Sweet Potatoes.

Grade	Moisture % Maryland Golden	Moisture % Jersey Orange	Moisture % Mean	Water Uptake % Maryland Golden	Water Uptake % Jersey Orange	Water Uptake % Mean
Jumbo	75.18	76.29	75.73	26.0	19.9	23.0
Market	72.66	73.22	72.93	21.6	18.3	19.9
Canning	73.00	73.35	73.17	29.5	23.7	26.6
Mean	73.60	74.28		25.7	20.6	

	Total Moisture F Value	Total Moisture L.S.D. @ 5%	Water Uptake F Value	Water Uptake L.S.D. @ 5%
Variety	7.33	N.S.	111.17**	1.0
Grade	53.33*	1.29	65.49	1.3

*Significant at odds of 19:1
**Significant at odds of 99:1

D. Effect of Pruning.

Storage roots obtained from the pruning experiment described under section I were used to determine the effect of a reduction in the top/root ratio of the sweet potato plant upon the moisture relations of the storage roots. Storage roots of both the market and canning grades were used for determinations of total moisture and water uptake.

The data presented in Table 34 shows that the total moisture percentage in the storage roots was increased by the late pruning, while there was no difference between early pruned plants and the check. No difference was found between the market and canning grades in moisture content.

The water uptake of the storage roots was affected by pruning with late pruning resulting in highest water uptake, while roots of the early pruned plants were intermediate between the late pruned and the check. This was true with both the market and canning grades as indicated by the lack of significance in the treatment x grade interaction. It was again found in this experiment that within each treatment potatoes of the canning grade exhibited a higher affinity to water than those of the market grade.

E. Effect of Hill Spacing.

Plants of Maryland Golden were set in the field at spacings of 10, 15, and 20 inches as previously described in section I. At harvest, storage roots of the market and the canning grades from each spacing were collected for studies of total moisture and water uptake. Although the crop of 1950 did not show any significant amount of cracking, some cracked potatoes were observed in this experiment and were

Table 34. Effect of Vine Pruning on the Moisture Content and Water Uptake of the Market and Canning Storage Root of Maryland Golden Sweet Potato.

Treatment	Moisture %			Water Uptake %		
	Market	Canning	Mean	Market	Canning	Mean
Check	74.27	76.64	75.45	19.9	24.5	22.2
Pruned July 15	74.85	76.03	75.44	20.9	26.8	23.9
Pruned Aug. 15	77.43	78.16	77.79	22.7	29.9	26.3
Mean	75.52	76.94		21.1	27.1	

	Total Moisture		Water Uptake	
	F Value	L.S.D. @ 5%	F Value	L.S.D. @ 5%
Grade	4.14	N.S.	22.80**	2.5
Treatment	4.95*	1.78	3.66*	3.1

*Significant at odds of 19:1
**Significant at odds of 99:1

collected for comparison with the sound storage roots.

The results obtained are shown in Tables 35 and 36. Analysis of the data obtained on the total moisture content indicates that neither spacing, cracking, nor grade had any effect on the percentage total moisture of the storage roots. From the data obtained on the water uptake (Table 36), it was found that at all spacings the water uptake of the canning grade was higher than that of the market grade. Furthermore, it was found that cracked potatoes exhibited greater affinity to water than potatoes free from cracking. The data further indicate that hill spacing did not exert any influence on the affinity of the storage roots to water.

F. Effect of Temperature on Water Uptake.

Water uptake was determined at temperatures of 32, 40, 50, 70, 85, and 120° F. to examine the effect of temperature during the testing period upon water absorption by the tissues of the storage root. Market size storage roots of Maryland Golden variety were used. The duration of the test was 24 hours. The results presented in Table 37 and Figure 28 indicate that at temperatures above 50° F. the absorption of water increased rapidly with increase in temperature up to 85° F. At 120° F. the tissues of the storage roots broke down and determination of water absorption was not possible.

Table 35. Effect of Hill Spacing on the Total Moisture Percentage in Market and Canning Grades of Cracked and Uncracked Maryland Golden Sweet Potatoes.

	Not Cracked			Cracked			
Space	Market	Canning	Mean	Market	Canning	Mean	Mean
20"	76.64	77.41	77.03	76.28	77.32	76.80	76.91
15"	76.61	75.91	76.26	75.29	76.38	75.84	75.66
10"	75.50	76.10	75.80	73.85	77.18	75.52	75.66
Mean	76.25	76.47	76.36	75.14	76.96	76.05	

	F Value	L.S.D. @ 5%
Spacing	0.80	N.S.
Grade	1.52	N.S.
Cracking	0.15	N.S.

Table 36. Effect of Hill Spacing on the Water Uptake of the Market and Canning Grades of Cracked and Uncracked Maryland Golden Sweet Potatoes.

	Not Cracked			Cracked			
Space	Market	Canning	Mean	Market	Canning	Mean	Mean
20"	22.43	24.40	23.42	25.01	25.64	25.33	24.37
15"	23.20	26.38	24.79	23.02	26.38	24.70	24.74
10"	22.40	26.26	24.33	25.33	26.63	26.00	25.16
Mean	22.68	25.68	24.18	24.46	26.22	25.33	

	F Value	L.S.D. @ 5%
Spacing	0.68	N.S.
Grade	18.93**	1.09
Cracking	4.49*	1.09

*Significant at odds of 19:1
**Significant at odds of 99:1

Table 37. Effect of Temperature During Testing on the Water Uptake of the Storage Roots of Maryland Golden Sweet Potato.

Temperature °F.	Water Uptake %
32	21.73
40	20.72
50	21.66
70	23.77
85	28.79
120	Tissue Breakdown
F Value	41.89**
L.S.D. @ 5%	1.67

**Significant at odds of 99:1

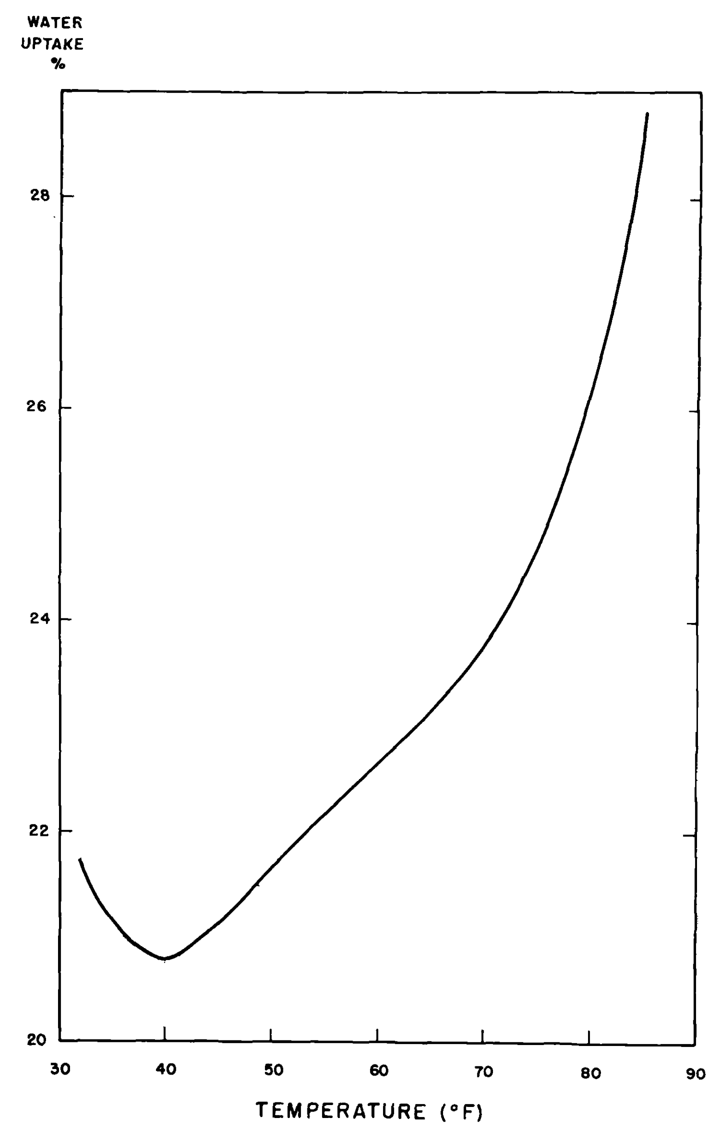

Figure 23. Effect of Temperature on the water uptake by the tissues of Maryland Golden sweet potatoes.

DISCUSSION

Cracking of sweet potatoes is a seasonal variable, and the year of 1949 represents a serious cracking season for the Eastern Shore of Maryland, while 1950 represents a non-cracking season. The results obtained from studies conducted in 1949, indicate that the varietal difference in susceptibility to cracking was the most consistent of any factor measured. Of the two varieties tested in 1949, Maryland Golden was found to be much more susceptible to cracking than was Jersey Orange. A varietal difference in susceptibility to cracking has likewise been reported in other crops, including Irish potatoes (47), tomatoes (8), apples (40), and cherries (17). The time of planting was also found to be an important factor involved in cracking in 1949. When Maryland Golden was planted at five successive dates at two-week intervals, cracking was highest in the first and fourth plantings. Jersey Orange did not show this effect, however, and cracking was slightly higher in the first planting, than in any of the other four plantings. With respect to the effect of hill spacing, a trend toward increased cracking with the increase in the distance between the plants was observed, although the data did not exhibit statistical significance. Propagation of sweet potatoes by vine cuttings resulted in a higher percentage of cracking than propagation by sprouts.

The Maryland Golden variety may be characterized by its large storage roots, whereas Jersey Orange produces a larger number of smaller roots. Within each variety, delay in planting seems to be the strongest factor depressing both yield and size of storage roots. This effect of time of planting was stronger in Maryland Golden than in Jersey Orange. Vine pruning also decreases the size of storage roots, and late pruning is more effective in this respect than early pruning. Hill spacing studies indicate that the size of the storage roots was reduced with a decrease in the distance between the plants. This effect, however, is more obvious when a wide range of spacings are tested. The two methods of propagation, sprouts and vine cuttings did not show any difference in regard to their effect on the size of the storage roots. In studying the effect of certain factors on the size of the storage roots, calculation of the average weight per root seems to be more suitable for the mathematical evaluation of the data than the use of a grading system alone, although the grading system is most suitable for a presentation of the data for practical application.

In contemplating the cracking problem with the previous information as a background, it may seem that the susceptibility of Maryland Golden to cracking may likely be due to the production of large storage roots. Results of hill spacing studies, may also indicate that cracking tends to increase with the increase in size of storage roots. Date of planting studies indicate, however, that the size of storage roots could not be the only factor involved in cracking. The first and fourth plantings resulted in the highest percentage of cracking in 1949, although the first planting produced large potatoes while the fourth produced relatively small roots. Furthermore, vine cuttings resulted in more cracking than sprouts, while the storage roots produced by the two methods were not different in size. The effects on cracking of date of planting and of method of propagation may again lead to the hypothesis that there is a certain physiological age at which the storage roots are most affected by conditions causing cracking.

Studies in 1950 regarding the development of the storage roots show that varieties of sweet potatoes differ in their growth behavior. In one group, including Maryland Golden, Jersey Orange, and B-5999, the rate of gain in the weight of the storage root increased throughout the season, while in a second group, including Porto Rico, L-241, and Australian Canner, the rate of gain in the weight per storage root dropped towards the end of the season. The variety Allgold, however, was unique and is characterized by a rapid rate of growth during the first part of the season, and progressively slows down until the end of the season.

In general, the increase in yield per plant in the first half of the growing season is due to both increase in number and weight of the storage roots, while in the second half it is primarily dependent upon the increase in weight of the roots. The time required for reaching the final number of storage roots seems to be a varietal characteristic. The varietal differences in the mode of growth and development indicate different temperature relationships, but more research must be done in this field before such differences in growth may be properly explained.

That Maryland Golden produces larger storage roots than Jersey Orange has been previously mentioned. In a comparison of the growth curves of the two varieties, it was found that this varietal difference in root size is due primarily to the difference in the growth rate towards the end of the season. The growth curves of both varieties are very similar during the first twelve weeks, yet during the last five weeks of the season, Jersey Orange has a slower rate of growth than Maryland Golden. In both varieties, the rate of growth was accelerated by a delay in planting, reaching a maximum rate with the third date of planting (June 8) and exhibiting a decreased rate again at the fourth date (June 22). This effect of the date of planting again suggests that there must be a close relation between temperature and rate of growth of the storage roots. Accumulative day-degree summations were correlated with the square root of the weight of the storage roots at the successive stages of development, and high correlation coefficients were obtained. Base-lines of 45° F. and 50° F. are considered to be most suitable for Maryland Golden and Jersey Orange respectively. Additional information is needed, however, concerning the temperature requirements at different stages of development of the sweet potato plant. Stier (36) found in the tomato that different stages of development have different base-lines.

Since the occurrence and severity of cracking varies from season to season, it would be logical to consider that certain environmental conditions are the responsible causal factors. Comparing the weather conditions in 1949 and 1950, mean temperatures were higher in the former season than in 1950 over the greater part of the season. In 1949, the mean temperature decreased steadily after the end of July, and the last month of the season was cooler in 1949 than in 1950.

Furthermore, in 1949, two drought periods prevailed during the late parts of June and July, accompanied by very high temperatures (reaching a high of 104° F.), while in 1950 a drought period occurred during the last three weeks of August. Ogle (24) has found that in the sandy loam soil where these experimental plots were located, a drought period of two weeks would decrease the soil moisture content from field capacity to wilting percentage, in the upper 12 inches. Although no significant cracking was observed in 1950, it is interesting to observe that of the small vine potatoes developed during the drought period 35.5 per cent were cracked in Maryland Golden and 13.5 per cent were cracked in Jersey Orange. Only a very slight amount of cracking was observed on the storage roots produced on the main root system. This would indicate that the vine potatoes were at the susceptible age for cracking, and that drought alone can cause cracking in such roots.

As previously stated, the highest percentage of cracking in Maryland Golden sweet potatoes in 1949 occurred in the first and fourth plantings. In that year the first drought period occurred when the plants of the first planting were 7 to 8 weeks old, while the second drought occurred when the plants of the fourth planting were 5 to 6 weeks old. Studies of 1950 temperatures reveal that 8-week-old plants of the first planting, and 6-week-old plants of the fourth planting, had received approximately the same summations of day-degrees above 45° F., and also that their storage roots were similar in weight. This would indicate that in 1949, the storage roots of the first and fourth plantings may have been subjected to drought when they were at the same physiological age, and this age may have been the most susceptible to cracking.

Based on the climatic conditions that prevailed during 1949, it may be hypothesized that cracking may occur in a year characterized by early drought periods, and with low temperatures and ample soil moisture towards the end of the season. Verner (40), referring to cracking in apples, explains that periods of hot, dry weather can limit the extensibility of the hypodermis and cause premature cessation of growth in this layer, and when such fruits are subjected to conditions of low evaporation they crack. Cracking in apples is, therefore, assumed to be due to an internal pressure caused by the accelerated growth of the fruit and the increase in hydration of the tissues, exceeding the extensibility of the hypodermal layer. Verner also suggests that there may be a certain stage of development when the fruit is most susceptible to cracking. Frazier and Bowers (8) found that cracking in tomatoes occurs when a drought period is followed by conditions of low transpiration rate, and that fruits are most susceptible to cracking between the pink and the red stages. In Irish potatoes, Werner (46) and Werner and Dutt (47) found that cracking is most severe under cool moist weather conditions, which result in high turgidity of the tissues.

In sweet potatoes, warm temperature and high humidity are both necessary for the activity of the tissues of the storage roots. This tissue activity is depressed or may be inhibited at low temperatures or under low humidities (3). When tissue activity was measured by wound tissue formation, the current work indicates that roots of

Maryland Golden, which is very susceptible to cracking, have lower tissue activity than Jersey Orange which is comparatively resistant to cracking. It was also found that at low humidity the tissues of Maryland Golden were completely inactive, while Jersey Orange still exhibited some activity. Varietal difference in tissue activity of Irish potatoes has been reported by Artschwager (2), where he found that the tissues of the Irish Cobbler variety are more active than the tissues of the Russet Rural variety. The Jersey Orange variety is also characterized by its high meristematic activity which is represented in the formation of abundant secondary cambiums, and a wide active cambial ring. Maryland Golden, on the other hand, has a narrower cambial ring and less secondary cambium than Jersey Orange. According to Levitt (19), meristematic tissues are less susceptible to drought injury than more mature tissues. Similar to the findings of Kertesz and Nebel (17) in cherries, the cells of the pericyclic parenchyma of Jersey Orange are more uniform than Maryland Golden. In the latter the cells of the pericyclic parenchyma are interspersed by irregular areas of large cells, which may attribute to the weakness of this texture.

When prolonged drought periods prevail, during the early part of the season, the young storage roots may be located in an environment unfavorable for their tissue activity. Under such conditions the outer tissues of the root may be completely inactivated, while growth may be taking place in the vascular cylinder utilizing moisture supplied by the fibrous roots which reach a considerable depth in the soil. Such an unbalanced growth between the outer and inner tissues is expected to result in an internal pressure which may cause rupture of the inactive outer tissues. It is postulated that a variety with low tissue activity, such as Maryland Golden, would be more susceptible to such cracking than a variety such as Jersey Orange which exhibits high tissue activity. With the resumption of favorable environmental conditions, healing of the ruptured areas will take place, and as the roots develop the healed cracks will become shallower. Such roots may heal to the extent that they will appear almost normal.

The latter part of the 1949 growing season was characterized by cool weather and a high soil moisture content. Low temperatures were found to retard the activity of the sweet potato tissues in the microenvironment study. It is hypothesized that activity of the outer tissues of the storage roots was retarded under such conditions. These tissues may have been completely inactive during the cool night periods. Furthermore, such climatic conditions would be expected to depress the transpiration rate, resulting in hydration and turgidity of the tissues of the root (15). This would subject the outer tissues to an internal pressure, and when the limit of their extensibility is reached, further growth of the axis of the root would result in cracking. As previously mentioned, Maryland Golden has a faster growth rate during the last month of the season than does Jersey Orange. This would make Maryland Golden more apt to crack, and cracking would be most severe in storage roots which have areas of weak tissues, such as roots which were subjected to cracking during the early stages of their development. Ogle and Scott (25) found in 1951 that cracking significantly increased towards the end of the season. Climatic conditions which result in a low evaporation rate have been reported to induce severe cracking of Irish potatoes (47), tomatoes (8), apples (39), and cherries (38).

Kertesz and Nebel (17) found that varieties of cherries susceptible to cracking exhibit a higher affinity for water than the resistant varieties, and that this affinity is due to a high content of colloidal pectins. Verner and Blodgett (42), on the other hand, attribute this water uptake to a high osmotic pressure. Kramer and Currier (18) have recently proposed that a distinction between osmotic and imbibitional forces in water uptake by plant cells is not practical. In the present work, it was found that the different varieties of sweet potatoes vary in their affinity to water. Tissues of Maryland Golden roots exhibited a higher affinity to water than did Jersey Orange. Studying the affinity to water of the vines, it was found that the water uptake decreased as the plants grew older, and that at all stages of development, the vines of Jersey Orange exhibited a higher affinity to water than did Maryland Golden. According to these findings it would be expected that under conditions of low temperatures and high humidity, the tissues of Maryland Golden storage roots would reach turgidity faster than would Jersey Orange.

Verner (39), studying the physiology of cracking in apples, found that the osmotic pressure of the tissues underneath a crack is higher than any other part of the fruit and suggests that such as osmotic gradient results in water movement to this region and causes cracking. The current study shows that water uptake was higher in cracked roots than in sound roots. It is questionable, however, whether this water uptake is the cause of cracking, or whether it is merely a result of cracking from the subjection of the tissues to partial dehydration.

It is interesting to observe that vine pruning is among the factors that affect both moisture content of the roots and their water uptake. Late pruning increased the moisture content of the roots and their affinity to water. The moisture content also differed with the size of storage roots, being higher in the roots of the jumbo grade than either the market or the canning grades, while water uptake was highest in the storage roots of the canning grade, followed by the jumbo grade, and lowest in the market grade. Water uptake by the tissues of roots was also found to increase with the increase in temperature. According to these findings, the use of storage roots of uniform size, and constant temperature, would be necessary in water uptake determinations.

Comparing the results of this study with the findings of the previous workers, only limited explanations can be proposed. Findings that applications of lime may increase cracking (20) might be explained by the dehydrating effect of lime when moisture is a limiting factor. Results showing that high applications of nitrogen increase cracking (20, 25) are possibly related to the effect of nitrogen on the rate of growth of the storage roots. Since high rates of nitrogen tend to increase the rate of growth, a greater internal pressure would be expected to develop within the axis when the storage root is located in an environment unfavorable for the activity of the outer tissues. Meristématic activity of the tissues of the roots is a necessary factor for a well balanced growth. The results obtained by Willis (48) in regard to reduction of cracking with an application of borax seem feasible since it is known that adequate boron favors meristematic activity, in addition to its regulating effect on moisture content of the tissues. Negative results obtained by Lutz et al. (20) concerning borax might have been expected since those soils were adequately supplied with boron. Ogle (24) was able to decrease cracking by using alpha-napthaleneacetic acid as a foliar spray. The results of Kramer and Currier (18) would seem to apply here. These authors suggest that the effect of a growth regulator is to increase the elasticity of the cell walls. It is, therefore, believed that increased elasticity would release the internal pressure exerted on the outer tissues of the storage root, thus reducing the incidence of cracking.

Lutz et al. (20) stated that the factors that induce cracking may also be responsible for storage decay. The results reported herein concerning tissue activity corroborate this view. Low tissue activity makes the storage root more subject to cracking, and also retards healing of injured tissues during the curing period. Greater losses of Maryland Golden than of Jersey Orange are encountered during storage. The lower tissue activity of Maryland Golden is seen as a factor for the slower rate of healing and poorer keeping quality. It is believed that the tissue activity test described in this study may be a useful tool for the sweet potato breeder, in the indexing of keeping quality of new sweet potato varieties, and for determining the curing requirements of the different types.

Cracking of sweet potatoes may be a serious problem when drought periods occur during the early stages of development of the storage roots, and when comparatively low temperatures accompanied by high soil moisture prevail at the end of the season. Under such conditions a delay in harvest would be inadvisable. The results obtained by Ogle

(24) from the use of growth regulators seem to be promising. Since the varietal difference in susceptibility to cracking was more consistent than any other factor, however, the ideal solution of the problem remains in the hands of the plant breeder.

SUMMARY AND CONCLUSIONS

In the year 1949 sweet potatoes were subjected to severe cracking along the Eastern Shore of Maryland. Data obtained in that year indicate that the varietal difference in susceptibility to cracking was the most consistent of any factor measured. Percentage of cracking was much higher in Maryland Golden variety than in Jersey Orange variety. Cracking in Maryland Golden was also greatly affected by the time of planting, and among five successive dates of planting (May 6, May 21, June 6, June 21, and July 6) the first and fourth dates resulted in more cracking than any of the three other dates. Storage roots produced from vine cuttings had a higher percentage of cracking than those produced from sprouts. In 1950 studies were conducted in an effort to explain the results obtained in 1949, on physiological and histological bases, and to add to the limited information on the growth and development of the sweet potato.

Sweet potato varieties differ in their growth behavior, in regard to increase in size and number of the storage roots. In general the increase in yield of the sweet potato plant in the first half of the season is due to increase in number and weight of the storage roots, while in the second half it is primarily due to the increase in weight of the roots. Varieties producing large roots have a lesser number of storage roots than varieties of smaller size roots. Comparing the two varieties Maryland Golden and Jersey Orange, the former produces larger storage roots than the latter. Growth of the storage roots is similar in both varieties except near the end of the season when the rate of growth of Maryland Golden is higher than Jersey Orange. In both varieties the rate of growth is closely correlated with temperature and the delay in planting increased the growth rate. High correlations were obtained when day-degree summations were correlated with the square root of the weight of the root, and base-lines of 45° F. and 50° F. appear to be most suitable for Maryland Golden and Jersey Orange respectively.

Histological examination reveals that Maryland Golden and Jersey Orange differ in their structure. In the young storage roots Maryland Golden has much larger xylem vessels than Jersey Orange. With the development of the pericyclic parenchyma the outer tissues of Maryland Golden were found to be more tangentially stretched than Jersey Orange. In the mature roots Jersey Orange has more uniform pericyclic parenchyma, a wider cambial ring and more active secondary cambium than Maryland Golden. Tissue activity was studied under microenvironmental conditions and measured by the formation of wound tissues. Jersey Orange was found to have higher tissue activity than Maryland Golden especially under conditions of low humidity when the tissues of the latter are completely inactive. At low temperature of 50° F. no tissue activity was observed in either variety regardless of humidity.

Storage roots of the different sweet potato varieties differ in their moisture content and in their capacity to absorb water. Roots of Maryland Golden have a higher affinity to water than the roots of Jersey Orange. In both varieties the water uptake by the vines declined as the plants grow older. At all stages of development, however, the vines of Jersey Orange exhibited a higher affinity to water than Maryland Golden. It would be expected, therefore, that under weather conditions causing a low transpiration rate, the tissues of Maryland Golden storage roots would reach turgidity faster than Jersey Orange.

Cracking of sweet potatoes may be described as rupture of the inactive outer tissues of the storage root due to internal pressure exerted by the expanding central axis. Inactivity of the outer tissues may be the result of low humidity or low temperature. It may be postulated that severe cracking will result when prolonged drought periods occur early in the season, and when cool temperatures accompanied by high soil moisture prevail at the end of the season. The season of 1949 conformed to these conditions.

During early drought periods the young storage roots may crack as a result of the inactivity of their outer tissues, especially in a variety in which the tissues are completely inactive under dry conditions. Storage roots seem to be most susceptible to such cracking at a certain physiological age, and it is suggested that, in 1949, Maryland Golden plants of the first and fourth plantings were subjected to drought periods when most of their storage roots were at that critical age. With the resumption of favorable environmental conditions, healing of such cracks will take place, although such roots are expected to be weaker in structure than sound roots.

At the end of the season, if temperature is comparatively low and soil moisture is high, the storage roots may be again subjected to cracking, which would be most severe in storage roots previously injured during their early stages of development. Such climatic conditions would inhibit the activity of the outer tissues and would result in turgidity of the root, thus exerting an internal pressure on the inactive outer tissues. Under such conditions, a variety (e.g., Maryland Golden) which exhibits low tissue activity, less active cambium, non-uniform pericyclic parenchyma, high water affinity by the storage roots and low water affinity by the vines, and a high rate of growth at the end of the season, would be most susceptible to cracking.

LITERATURE CITED

1. Artschwager, E. On the anatomy of the sweet potato root, with notes on the internal breakdown. Jour. Agr. Res. 27: 157-166. 1924.

2. ______________ Wound periderm formation in the potato as affected by temperature and humidity. Jour. Agr. Res. 35: 999-1000. 1927.

3. ______________ and Starrett, R. C. Suberization and wound periderm formation in sweet potato and gladiolus as affected by temperature and relative humidity. Jour. Agr. Res. 43: 353-364. 1931.

4. ______________________________ Suberization and wound cork formation in the sugar beet as affected by temperature and relative humidity. Jour. Agr. Res. 47: 669-674. 1933.

5. Cochran, W. G. and Cox, G. M. Experimental Designs. New York: John Wiley and Sons, Inc. 1950.

6. El-Kattan, A. A. The yield and size of sweet potatoes as influenced by method of propagation, date of planting, hill spacing, and row spacing. M. S. Thesis. Univ. of Maryland. 1950.

7. Frazier, W. A. A study of some factors associated with the occurrence of cracks in the tomato fruit. Proc. Amer. Soc. Hort. Sci. 32: 519-523. 1934.

8. ______________ and Bowers, J. L. A final report on studies of tomato fruit cracking in Maryland. Proc. Amer. Soc. Hort. Sci. 49: 241-255. 1947.

9. Garcia, F. Sweet potato culture. N. M. Agr. Exp. Sta. Bul. 70. 1909.

10. Gardner, V. R., Bradford, F. C., and Hooker, H. D. The Fundamentals of Fruit Production. New York: McGraw-Hill Co. 1922.

11. Harter, L. L. and Weimer, J. L. A monographic study of sweet potato diseases and their control. U. S. Dept. of Agr. Tech. Bul. 99. 1929.

12. ______________ and Whitney, W. A. Influence of soil temperature and soil moisture on the infection of sweet potatoes by the black rot fungus. Jour. Agr. Res. 32: 1153-1160. 1926.

13. Hartman, H. and Bullis, D. E. Investigations relating to the handling of sweet cherries with special reference to chemical and physiological activities during ripening. Ore. Agr. Exp. Sta. Bul. 247. 1929.

14. Hartman, J. D. and Gaylord, F. C. Yield of sweet potatoes as affected by date of harvest. Proc. Amer. Soc. Hort. Sci. 42: 514-516. 1943.

15. Hasselbring, H. Behavior of sweet potatoes in the ground. Jour. Agr. Res. 12: 9-17. 1918.

16. Hayward, H. E. The Structure of Economic Plants. New York: Macmillan Co. 1938.

17. Kertesz, Z. I. and Nebel, B. R. Observations on the cracking of cherries. Plant Physiol. 10: 763-771. 1935.

18. Kramer, P. J. and Currier, H. B. Water relations of plant cells and tissues. Ann. Rev. Plt. Physiol. 1: 265-284. 1950.

19. Levitt, J. Frost, drought, and heat resistance. Ann. Rev. Plt. Physiol. 2: 251-253. 1951.

20. Lutz, J. M., Deonier, M. T., and Walters, B. Cracking and keeping quality of Porto Rico sweet potatoes as influenced by rate of fertilizer, nitrogen ratio, lime, and borax. Proc. Amer. Soc. Hort. Sci. 54: 407-412. 1949.

21. McCormick, F. A. Notes on the anatomy of the young tuber of Ipomoea batatas, Lam. Bot. Gaz. 61: 388-398. 1916.

22. Mullins, R. S. Sweet potato cracking. Vegetable Growers News. Vol. 5, No. 8. Feb. 1, 1951. Va. Truck Exp. Sta., Norfolk, Va.

23. Nusbaum, C. J. Studies of boron deficiency of sweet potatoes. Phytopath. 37: 435. 1947.

24. Ogle, W. L. Personal communications.

25. __________ and Scott, L. E. The effect of fumigation, nitrogen level, and soil moisture conditions upon cracking of sweet potatoes. Trans. Peninsula Hort. Soc. (Bul. Del. St. Bd. Agr.) 41 (5): 35-38. 1951.

26. Priestley, J. H. and Woffenden, L. M. The healing of wounds in potato tubers and their propagation by cut sets. Ann. Appl. Biol. 10: 96-115. 1923.

27. Pumphry, F. V. and Harris, L. Cracking of Triumph potatoes. Amer. Pot. Jour. 26: 355-361. 1949.

28. Robertson, B. The Chemical Basis of Growth and Senescence. Philadelphia: Lippincott Co. 1923.

29. Sakr, E. M. Effect of temperature on yield of the sweet potato. Proc. Amer. Soc. Hort. Sci. 42: 517-518. 1943.

30. Scott, L. E. Factors associated with cracking of sweet potatoes. Trans. Peninsula Hort. Soc. (Bul. Del. St. Bd. Agr.) 39 (5): 37-40. 1949.

31. __________, Stark, F. C., Matthews, W. A., El-Kattan, A. A., Ogle, W. L., and Duncan, A. A. Progress report on sweet potato cracking experiments. Report Md. Agr. Soc. 35: 215-220. 1950.

32. Sinnott, E. W. The relation of growth to size in cucurbit fruits. Amer. Jour. Bot. 32: 439-445. 1945.

33. Snedecor, G. W. Statistical Methods. Iowa State College Press. 4th edition. 1946.

34. Stark, F. C. Factors influencing growth of pods and the development of the inner mesocarp in pods of the snap bean. M. S. Thesis. Univ. of Maryland. 1941.

35. Starnes, H. N. Sweet potatoes. Ga. Agr. Exp. Sta. Bul. 25. 1894.

36. Stier, H. L. A physiological study of growth and fruiting of the tomato with reference to the effect of certain climatic and edaphic conditions. Ph.D. Thesis. Univ. of Maryland. 1939.

37. Thompson, R. C. and Beattie, J. H. Proximal dominance in sweet potatoes. Proc. Amer. Soc. Hort. Sci. 28: 270-275. 1931.

38. Tucker, L. R. A varietal study of the susceptibility of sweet cherries to cracking. Idaho Agr. Exp. Sta. Bul. 211. 1934.

39. Verner, L. A physiological study of cracking in Stayman Winesap apples. Jour. Agr. Res. 51: 191-222. 1935.

40. __________ Histology of apple fruit tissue in relation to cracking. Jour. Agr. Res. 57: 813-824. 1938.

41. __________ Reduction of cracking in sweet cherries following the use of calcium sprays. Proc. Amer. Soc. Hort. Sci. 36: 271-274. 1938.

42. __________ and Blodgett, E. C. Physiological studies of cracking of sweet cherries. Idaho Agr. Exp. Sta. Bul. 184. 1931.

43. Weaver, J. E. and Bruner, W. E. Root Development of Vegetable Crops. New York: McGraw-Hill Co., 1st edition. 1927.

44. Weimer, J. L. and Harter, L. L. Wound cork formation in the sweet potato. Jour. Agr. Res. 21: 637-647. 1921.

45. Weiss, F. and Lauritzen, J. J. Factors in the inception and development of fusarium rot in stored potatoes. U. S. Dept. Agr. Tech. Bul. 62. 1928.

46. Werner, H. O. The cause and prevention of mechanical injury of potatoes. Nebr. Agr. Exp. Sta. Bul. 260. 1931.

47. ____________ and Dutt, J. O. Reduction of cracking of late crop potatoes at harvest time by root cutting or vine killing. Amer. Pot. Jour. 18: 189-208. 1941.

48. Willis, L. G. Apply borax to improve quality of sweet potatoes. N. C. Spec. Circ. No. 1. 1943.

VITA

Name: Ahmed Azmi El-Kattan.

Degree: Doctor of Philosophy, 1952.

Date of Birth: March 21, 1925.

Place of Birth: Cairo, Egypt.

Secondary Education: Ibrahimia High School, Cairo, Egypt.

Collegiate Institutions attended:

Fouad 1st University, College of Agriculture, Egypt, 1941-45. Bachelor of Science (Agr.) June, 1945.

University of Maryland, 1948-52, Master of Science, 1950. Doctor of Philosophy, 1952.

Publications:

1. El-Kattan, A. A. and F. C. Stark, Jr. A comparison of sprouts and vine cuttings for sweet potato production. Trans. Penin. Hort. Soc. (Bul. Del. St. Bd. Agric.) 39 (1949) : 34-37. 1950.

2. ________________________________ Tissue activity and structural differences in the storage roots of Maryland Golden and Jersey Orange sweet potatoes as related to cracking. (In press)

3. Scott, L. E., Stark, F. C., Matthews, W. A., El-Kattan, A. A. Ogle, W. L., and Duncan, A. A. Progress report on sweet potato cracking experiments. Report Md. Agr. Soc. 35: 215-220. 1950.

Positions held:

Teaching and Research Assistant, Fouad 1st University, College of Agriculture, Department of Horticulture (Vegetables), 1946-48.

Study leave at University of Maryland, Department of Horticulture, 1948- .

Research Assistant, University of Maryland, Department of Horticulture, 1951-52.