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Place and Season Effects on Yields and Starch Content of 38 Kinds of Sweetpotatoes

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GREATER YIELDS RICHER IN STARCH ARE NEEDED

This circular is essentially a progress report on one phase of a large, long-time, cooperative sweetpotato improvement and production project conducted by the agencies named above. A major object of the project is the breeding or selection and introduction of new and improved varieties that will be more productive and better adapted than the old ones that have been grown in this country. Better varieties are being sought for two different purposes: (1) For manufacture of starch or other products and for livestock feed; and (2) for human food. For industrial or stock-feeding purposes appearance is of minor importance, while the greatest total yield per acre and highest possible content of starch and other solids are sought. Varieties for table use must be not only productive but attractive in form, color, and eating quality.

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In a broad improvement program of this kind it is desirable that new varieties be developed that will be superior in not only one or a few districts, but over large areas or even for the entire sweetpotato-producing territory of the country, if possible. It thus becomes important to know how different sections or areas affect the quality as well as the yield of the crop. Do some parts of the country consistently produce sweetpotatoes with higher starch content and total solids than do other parts; and if so, do varieties respond alike or differently to this place effect upon starch content? These questions obviously have a most important bearing on the locating of a manufacturing enterprise that uses sweetpotatoes as the raw product. Furthermore, knowledge of the relative stability of starch and total solids content within varieties is of great value in planning and carrying out the extensive field testing that must be done in evaluating new varieties.

The purposes of this circular are: (1) To show how starch content as well as yield of sweetpotatoes as a crop—consisting of numerous varieties—is affected by place of culture and season; (2) to show some individual varietal differences in starch content and starch production averaged over a large region as a whole; and (3) to show whether there are important differences in the extent to which environment affects starch content and production in some varieties as compared with others.

The cooperative work described in this circular has led to some definite conclusions that are of immediate practical value and considerable potential importance.

Location and seasonal conditions at any one place have marked effects on the percentage of starch in sweetpotatoes as well as upon the total yields and the commercial grades of the roots produced.

Whenever drought is serious enough to reduce greatly the yields of sweetpotato roots per acre, the percentages of starch and of total dry matter in the roots are markedly reduced. Contrary to expectations, there was no consistent effect of excessive rainfall, as compared with medium or normal rainfall, upon the starch and dry-matter content of the roots.

There is a marked tendency for the starch content of the roots to vary inversely with the degrees of latitude of the location where they are grown. This tendency does not appear to be correlated with the rainfall, temperature, or length of growing season to which the crops were exposed for the last 4 months of the season. Neither is there any clear association between starch content and soil fertility as indicated by yields.

Very marked and consistent differences among varieties were evident in starch content as well as in yield. Although the relative starch content among varieties varied somewhat from year to year and from place to place, varietal differences were highly significant with reference to interactions of variety with season and with locality.

Several seedlings and introductions were significantly superior to the varieties commonly grown in the United States in starch content, in yield of roots, and in amount of starch produced per acre.

Although many varieties performed better in some places than in others, as compared with other varieties, a few were outstandingly good in all tests. This demonstration of the possibility of obtaining superior varieties of very wide adaptability is of particular practical importance as well as of technical interest. Low-yielding or mediocre strains observed in any of the locations involved in this work can be discarded more promptly than formerly, since it has been shown unnecessary to retain them on the chance that they might prove outstanding elsewhere. It appears feasible to obtain superior new varieties of such wide adaptability that a multiplicity of kinds will be unnecessary in order to meet regional or local requirement.

These comments and conclusions are not intended to apply to such quality factors as color, smoothness, and palatability in sweetpotatoes for table use. Reports of studies of market and table qualities will be made later. It appears certain, however, that it will be more difficult to obtain higher yielding, disease-resistant, more widely adapted varieties that are superior in eating quality to our best present kinds than to obtain superior kinds for industrial use or stock feed.

METHODS AND MATERIALS

Late in 1939 workers of the eight research agencies cooperating in this study jointly planned a long-time program of sweetpotato improvement and research, of which this study is a part. With one exception (p. 14), uniform objectives, experimental designs, procedures, and experimental materials were involved throughout. Field work was conducted during 1940, 1941, and 1942 at Beltsville, Md.; Onley, Va.; Blackville, S. C.; Experiment and Tifton, Ga.; Meridian and Laurel, Miss.; Baton Rouge, La.; and Gilmer, Tex. The tests at Onley, Va., were made on soil rather heavily infested with wilt primarily to determine varietal reactions to wilt. Because of the heavy mortality of and the damage to many sorts at Onley, the data from that location are presented separately.

Field plots consisted of two-row plots, 30 feet long, arranged in 7 by 7 lattice squares replicated four times. The rows were 4 feet apart except at Laurel, where they were 3½ feet apart. At each location the locally prevailing methods of field culture and fertilizing were used in order that the results would be as representative of the section as possible. Table 1 summarizes the salient features of the conditions of the several tests.

At harvest, shortly before or immediately after frost, the roots were plowed out and graded,[12] and each grade was weighed. Only the data on the No. 1 grade and total yields are presented in this circular. Immediately upon harvesting, 10 roots that were typical of the plot in which they grew were taken from each plot in replicates 1 and 3 or 2 and 4 in each test. They were washed, wiped with a dry cloth, and halved lengthwise; then one-half of each was sampled with a sugar-beet rasp. The pulp from the 10 roots was thoroughly mixed, and duplicate small samples were weighed out and placed in 95-percent alcohol in sturdy screw-cap vials for shipment to the laboratory at the United States Horticultural Field Station, Meridian, Miss., for starch determination. These determinations were made by Belton Walters and others of the Meridian station by the Balch method,[13] developed for sweetpotatoes. Dry-matter determinations were made at the time starch samples were taken, but the details of those results are not presented.

[12] The roots were graded for size and shape approximately according to requirements of U. S. Jumbo, U. S. No. 1, and U. S. No. 2 grades, issued by the Bureau of Agricultural Economics, U. S. Department of Agriculture, September 8, 1925. Mechanical damage was not considered in this grading because the primary interest was in the distribution of sizes and shapes of roots produced. In some tests culls and No. 2's were recorded together.

[13] BALCH, R. T. RAPID DETERMINATION OF STARCH (ROOT) WITH SODIUM HYPOCHLORITE. Indus. and Engin. Chem., Analyt. Ed., 13:246-248. 1941.

TABLE 1.—*Cultural and weather conditions under which the sweetpotato tests were conducted at 9 locations in 1940, 1941, and 1942*

Place and year	Soil	Fertilizer		Dates		Growth period	Last 4 months	
		Analysis	Amount	Planted	Harvested		Total rainfall	Mean temperature
Beltsville, Md.:		*Percent*	*Pounds*			*Days*	*Inches*	*°F.*
1940	Sassafras sandy loam	2-8-10	1,000	May 27	Oct. 10	136	11.7	71.4
1941	do	2-8-10	1,000	do	Oct. 13	139	13.9	72.9
1942	do	2-8-10	1,000	May 19	Oct. 9	143	20.9	71.1
Blackville, S. C.:								
1940	Marlboro sandy loam	4-8-8	1,000	May 20	Oct. 16	149	16.3	75.7
1941	Norfolk sandy loam	3-8-8	1,000	June 2	Oct. 22	142	16.3	77.8
1942	do	3-8-8	1,000	June 15	Oct. 20	127	22.9	78.1
Experiment, Ga.:								
1940	Cecil sandy clay loam	4-8-6	500	May 2	Nov. 4	186	15.2	73.0
1941	do	4-8-6	500	May 9	Nov. 5	180	12.0	77.5
1942	do	4-8-6	500	April 29	Nov. 2	187	17.2	73.0
Tifton, Ga.:								
1940	Tifton sandy loam	4-8-6	800	May 8	Oct. 22	167	18.6	75.2
1941	do	4-8-6	800	do	Nov. 10	186	12.6	78.5
1942	do	4-8-6	800	May 14	Nov. 11	181	13.5	76.4
Meridian, Miss.:								
1940	Norfolk-Ruston sandy loam.	4-10-7	1,000	May 16	Nov. 6	174	18.9	74.7
1941	do	4-10-7	1,000	May 22	Oct. 29	160	23.7	78.5
1942	do	4-10-7	1,000	May 13	Nov. 2	173	14.9	75.0
Laurel, Miss.:								
1940	Cahaba sandy loam	6-8-8	1,000	May 22	Oct. 6	137	24.5	76.4
1941	Kalmia sandy loam	6-8-8	[1] 800	May 7	Oct. 8	154	22.9	80.3
1942	Cahaba sandy loam	6-8-8	[2] 800	May 16	Oct. 12	149	18.8	77.1
Baton Rouge, La.:								
1940	Lintonia silt loam	4-12-4	400	May 29	Oct. 10	134	29.4	78.8
1941	do	4-12-4	400	May 19	Oct. 16	150	18.4	79.9
1942	do	4-12-4	400	May 25	Oct. 13	141	30.6	80.2
Gilmer, Tex.:								
1940	Bowie fine sand	4-8-10	600	Apr. 30	Oct. 7	160	13.2	78.5
1941	do	4-8-10	600	May 14	do	146	23.9	79.9
1942	do	4-8-10	600	May 1	Oct. 5	157	17.6	79.4
Onley, Va.:								
1940	Sassafras-Keyport sandy loam.	3-3-15	1,000	May 22	Oct. 9	140	12.4	73.5
1941	do	3-3-15	1,000	May 28	Oct. 21	146	8.6	73.7
1942	do	3-3-15	1,000	May 29	Oct. 25	149	23.1	72.8

[1] Side-dressed with 300 pounds of 6-8-8, 3 weeks after planting.
[2] Side-dressed with 300 pounds of 4-8-4, 3 weeks after planting.

The "varieties," or kinds, consisted of about a dozen named varieties long known to this country; four new varieties (Director; Wenholz 3; Wenholz 2; and Wannop, which was erroneously called Wennop [14]) developed by the Department of Agriculture of New South Wales, Australia, from which they had been obtained a few years earlier; about a dozen introductions from the Union of Soviet Socialist Republics, the East Indies, and the West Indies; and a number of seedlings (designated by numbers preceded by B-) grown at Beltsville, Md., from seed obtained from various sources. Some preliminary, and rather miscellaneous, studies on most of these sorts were reported by some of the authors of this circular and others.[14] Names that were

[14] STEINBAUER, C. E., HARTER, L. L., HOFFMAN, G. P., and others. COOPERATIVE TESTS OF SWEETPOTATO VARIETIES, INTRODUCTIONS, AND SEEDLINGS FOR STARCH PRODUCTION AND MARKET PURPOSES U. S. Dept. Agr. Cir. 653, 41 pp., illus. 1942.

supplied there for some of the numbers are not considered important for this circular.

Because of the limited supply of bedding stock and certain misfortunes at the beginning of this work at 9 locations, some varieties included in the plans of the lattice squares failed to produce enough plants in one place or another to complete the designs. These gaps were uniformly filled with the Porto Rico variety to permit accurate analysis of single tests. These misfortunes, however, left only 38 kinds that appeared in 8 places in all 3 years for inclusion in a combined analysis as randomized blocks for all tests.

For the combined tests as presented here intratest variation was disregarded, and the mean value of the 4 replicates in each test was used in constructing the tables for presentation and analysis of results. This condensation still gave a table containing 912 items for analysis, 24 values for each variety. Since in this presentation effects due to place, to year, and to variety, and to interactions among them are of primary interest, intratest variance is passed over. The data were analyzed by the conventional variance method described by Snedecor [15] and others. Differences required for significance, as shown in the several tables, have been calculated for the 5-percent level. Variety errors for combined places and years are based on a pooled variance of all interactions involving variety. The χ^2 test showed the variance of starch-content data to be homogeneous among locations, although the total variance of starch yields among locations was not. The error variances for starch yields were homogeneous, but those for root yields were not. Consequently, the differences required for significance are shown for each location separately in the tables.

RESULTS AT EIGHT PLACES

Yields

Tables 2 and 3 present the root yield data for 38 varieties grown for 3 years at all locations except Onley, Va. Table 4 shows the results of the variance analyses of the yields and other data. Table 5 summarizes the results obtained at Onley.

Highly significant differences in No. 1 and total yields occurred among varieties at each location (table 2) and for all locations combined despite the relatively high error in work with this crop. Porto Rico and Triumph may be considered as "check" varieties, since they are the most important at present for food and manufacture, respectively. It is of particular interest that the two best-yielding varieties for the combined tests, considering yields of No.1 and total roots, are two new seedlings, B–196, a starch type, and B–219, a table type. B–196 was significantly outyielded in total roots only by Wannop and 47442 at a single location, Beltsville; and in No. 1 grade by Director and B–219 at Blackville and by B–219 at Gilmer. Only Wannop significantly outyielded B–219 in any test, at Experiment and Laurel.

[15] SNEDECOR, G. W. STATISTICAL METHODS APPLIED TO EXPERIMENTS IN AGRICULTURE AND BIOLOGY. Ed. 3., 422 pp., illus. Ames, Iowa. 1940.

TABLE 2.—*Mean No. 1 grade and total yields per acre of 38 kinds of sweetpotatoes grown at 8 locations in 1940, 1941, and 1942*

Variety or seedling	Beltsville, Md.		Blackville, S. C.		Experiment, Ga.		Tifton, Ga.		Meridian, Miss.		Laurel, Miss.		Baton Rouge, La.		Gilmer, Tex.		Variety mean	
	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Big-Stem Jersey	95	251	108	285	28	119	89	184	127	220	49	82	92	172	32	150	78	183
Director	148	305	135	314	51	174	53	233	87	267	102	196	184	296	51	299	101	264
Florida	138	221	90	219	76	132	138	214	79	248	122	170	177	275	47	239	108	215
Mamevita	166	270	67	164	76	136	119	180	148	244	141	197	233	321	44	249	124	220
Myers Early	144	261	108	233	54	131	93	174	82	160	84	138	197	266	47	280	101	205
Nancy Hall	159	267	100	199	57	135	109	183	104	184	96	175	196	288	45	252	108	210
North Carolina No. 1	191	311	62	161	76	129	149	232	97	188	115	170	257	333	46	295	124	227
Norton	170	266	82	209	70	120	134	183	140	219	114	136	203	275	52	246	121	208
Pierson	235	360	89	268	66	153	99	208	83	213	88	146	192	265	28	283	110	237
Porto Blanco	83	160	76	188	33	107	107	177	83	166	62	105	149	250	25	218	77	172
Porto Rico	176	281	99	187	58	125	129	198	131	244	104	147	239	328	46	239	123	219
Purple Stem Triumph	187	260	76	210	65	116	150	219	133	224	157	215	171	241	40	255	123	217
Red Bermuda	155	297	92	255	69	153	112	237	103	244	86	140	199	291	26	277	104	237
Red Brazil	177	300	31	142	87	125	112	166	106	173	86	121	232	284	31	271	108	198
Southern Queen	164	263	79	172	56	134	119	213	152	261	117	168	189	244	24	271	113	216
Triumph	133	270	75	201	72	157	151	268	168	272	146	208	160	265	66	293	121	242
Unit I Porto Rico	174	272	101	201	64	139	155	256	163	280	118	166	253	338	56	290	135	244
Wenholz 1	222	338	99	269	62	160	149	226	177	296	126	180	255	348	46	316	142	267
Wenholz 2	232	363	91	251	72	155	182	269	168	298	135	190	249	329	56	277	148	267
Wannop	208	392	57	258	61	209	80	238	86	272	139	231	238	356	43	315	114	284
Yellow Strasburg	192	285	78	174	77	139	124	195	145	244	111	159	212	274	38	182	122	206
S-312	148	237	72	197	46	118	124	195	99	180	73	126	208	288	43	178	101	190
22437	113	229	65	185	43	109	80	144	90	190	63	113	124	190	39	154	77	164
24171	169	290	113	271	43	127	135	285	73	182	84	152	196	280	51	306	108	237
47442	127	259	87	217	44	122	74	184	106	213	92	145	185	257	49	257	96	207
47443	253	396	61	199	83	112	69	122	100	188	88	172	211	316	15	231	110	217
64377	118	221	57	161	35	97	125	188	140	225	106	145	203	268	30	184	102	186
85985	159	330	52	204	95	183	89	130	57	165	102	158	109	224	6	193	84	198
85986	176	276	95	206	54	99	104	143	107	186	78	119	192	256	38	194	106	185
021745	213	313	68	243	70	141	81	161	121	210	76	118	167	238	29	205	103	204
029878	174	287	74	182	67	149	107	168	128	219	126	164	[1] 236	[1] 280	62	320	123	221
029881	273	374	82	243	114	180	132	230	180	301	134	177	204	277	15	314	141	262
B-27	102	212	72	178	45	[1] 94	125	198	148	212	[1] 88	130	172	252	50	249	100	191
B-33	173	301	52	190	[1] 92	195	123	198	174	305	136	225	225	352	51	293	128	257
B-52	197	295	77	198	118	184	149	245	170	284	114	175	237	336	44	303	138	253
B-196	216	315	112	320	99	178	214	300	171	317	133	207	236	361	45	392	153	299
B-204	249	386	[1] 90	234	89	146	152	264	177	294	157	212	172	262	20	263	138	258
B-219	219	343	150	333	78	170	122	241	131	284	146	169	256	362	97	365	150	283
Place mean	175	291	84	220	67	141	120	206	125	233	108	162	200	285	41	261	115	225
Difference required for significance between varieties within places	64	73	22	70	24	38	50	70	62	73	43	56	38	54	25	78	20	26

[1] Calculated value; variety not grown.

TABLE 3.—*Mean No. 1 grade and total yields per acre of 38 kinds of sweetpotatoes at 8 locations for 3 years*

Place	1940		1941		1942		3-year mean	
	No. 1	Total	No. 1	Total	No. 1	Total	No. 1	Total
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Beltsville, Md	177	294	99	213	248	366	175	291
Blackville, S. C	82	307	45	120	124	232	84	220
Experiment, Ga	60	144	53	108	89	171	67	141
Tifton, Ga	71	142	131	215	157	262	120	206
Meridian, Miss	55	147	87	203	232	350	125	233
Laurel, Miss	78	138	76	109	170	239	108	162
Baton Rouge, La	136	220	226	289	239	346	200	285
Gilmer, Tex	33	268	31	256	60	262	41	261
Mean, all places	86	208	93	189	165	279	115	225
Difference required for significance:								
Between places for all years							59	89
Between years for all places							36	51
Between years for 1 place							106	155

TABLE 4.—*Variance analyses of data contributing to tables 2 and 6*

Source of variation	Degrees of freedom	Variance for—			
		No. 1 yield [1]	Total yield [1]	Starch percent	Starch yield [2]
Varieties	37	863	2, 396	97. 03	176. 6
Places	7	29, 344	31, 160	328. 05	1, 483. 2
Years	2	52, 579	62, 634	47. 61	4, 365. 2
Varieties × places	259	186	288	3. 65	15. 6
Years × places	14	4, 767	10, 444	90. 09	701. 6
Varieties × years	74	79	144	3. 28	10. 5
Varieties × places × years [3]	492	75	151	2. 24	9. 2
Total [3]	885				

[1] Variance values were calculated on pounds per plot. Conversion formula: Pounds per plot × 3.3 = bushels per acre.
[2] Variance values were calculated on pounds per plot. Conversion formula: Pounds per plot × 181.5 = pounds per acre.
[3] 26 missing values were supplied by calculation.

Of greater interest is whether these new seedlings significantly outyielded the standard varieties. For the combined locations, B–196 and B–219 significantly exceeded both Porto Rico and Triumph in yields of No. 1 grade as well as in total yield. Only at Tifton did the No. 1 yield of Porto Rico exceed that of B–219 (nonsignificantly) and in no case did total yield of Porto Rico exceed it. In three of the eight locations B–219 significantly outyielded Porto Rico. B–196 significantly outyielded Triumph in No. 1 grade in five places but was equaled or surpassed nonsignificantly in two places. At three places B–196 significantly surpassed Triumph in total yield, and it equaled or slightly surpassed it in the others.

Only the Australian introduction Wannop approached these two B seedlings in amount and consistency of total yields, while it was much lower in No. 1 yields. In most cases its No. 1 yields were only average or below, because so many roots were rough and of undesirable shape.

There were no significant differences in No. 1 or total yields among the three stocks of Porto Rico tested (Porto Rico, North Carolina No. 1, and Unit I Porto Rico), although the total yields of the last two

TABLE 5.—*Yields per acre, starch content, and response to wilt of 38 kinds of sweetpotatoes grown at Onley, Va., in 1940, 1941, and 1942* [1]

Variety or seedling	Yields per acre of— Roots: No. 1	Roots: Total	Starch	Starch content	Plants infected with wilt
	Bushels	*Bushels*	*Pounds*	*Percent*	*Percent*
Big-Stem Jersey	45	104	904	15.8	79
Director	72	270	3,089	20.8	29
Florida	113	239	2,827	21.6	10
Mameyita	90	184	1,933	19.1	65
Myers Early	77	160	2,024	[2] 23.0	[3] 59
Nancy Hall	109	210	2,576	22.3	51
North Carolina No. 1	98	217	2,339	19.6	57
Norton	142	218	2,698	22.5	13
Pierson	102	329	3,691	20.4	17
Porto Blanco	25	152	1,488	[2] 17.8	[3] 22
Porto Rico	108	219	2,252	18.7	61
Purple Stem Triumph	67	230	2,378	18.8	19
Red Bermuda	100	333	3,425	18.7	15
Red Brazil	94	309	3,348	19.7	14
Southern Queen	91	203	2,456	22.0	[3] 19
Triumph	134	183	2,234	[2] 22.2	[3] 12
Unit I Porto Rico	120	233	2,512	19.6	56
Wenholz 1	158	279	3,253	21.2	13
Wenholz 2	169	304	3,428	20.5	15
Wannop	127	374	3,661	[2] 17.8	[3] 3
Yellow Strasburg	95	227	2,559	[2] 20.5	[3] 10
S-312	38	131	1,527	21.2	15
22437	89	162	1,925	21.6	15
24171	106	243	2,432	18.2	12
47442	93	182	2,052	[2] 20.5	[3] 5
47443	47	288	2,439	15.4	9
64377	86	173	2,103	22.1	13
85985	20	242	2,036	15.3	10
85986	111	205	2,480	22.0	13
021745	110	291	3,489	21.8	10
029878	140	263	3,124	21.6	11
029881	79	361	3,296	16.6	31
B-27	46	130	1,373	19.2	30
B-33	124	288	3,311	20.9	12
B-52	77	262	2,752	[2] 19.1	[3] 9
B-196	135	289	3,560	22.4	24
B-204	176	340	3,646	19.5	18
B-219	160	320	3,291	18.7	18
Mean	99	241	[4] 2,651	20.0	23.5
Difference required for significance	72	88	------------	1.4	------------

[1] Starch determinations were made only for the 1941 and 1942 crops.
[2] Only 1 year's results.
[3] Only 2 years' results.
[4] Nonweighted mean.

tended to be slightly higher. The mean yields of No. 1 grade were nearly the same for all three.

Table 3 shows that there were very marked differences in yields among locations, due principally to differences in natural fertility of the soil and rainfall. Larger amounts of fertilizer are normally used on the crop in Maryland (1,000 to 1,200 pounds of 2–8–10 is common) than in the Georgia and Texas sections. Higher fertilization and earlier planting probably would have improved yields substantially on the poorer soils in some locations. Dry weather at Experiment, Ga., in 1941 held yields down. However, the yields shown for the various locations are rather typical of experiments in the respective sections or regions over a period of many years.

With the tests widely distributed from Maryland and Virginia to Louisiana and Texas it is a little surprising that so much difference in yields occurred between years for the combined locations. However, 3 years is a very small sample of years and may or may not give a fair indication of the differences that would be found over the same range of locations among another 3 consecutive years.

It has been suggested that different sections could grow numerous different kinds, each growing only 1 or 2 adapted varieties. This would be possible, but the work of both grower and distributor will be easier if better varieties that prove to be superior over a large part of the country can be found. To what extent do the present 38 varieties conform in various locations to the rank of their mean behavior?

Table 4 shows the variances for main effects and for interactions between these effects on yield. Variance for varieties is very much larger than for any interaction involving variety, showing that these varieties tend very definitely to hold their relative productivity or rank regardless of location. Although it is true that the relative total yields of some of the entire group of 38 varieties change somewhat from place to place, most of that variability in performance occurs among the medium or poor varieties. The highest yielding varieties are high everywhere tested in this work. B–196 is the highest yielder on the average, and Wannop, B–219, Wenholz 1, and Wenholz 2 follow closely. Arbitrarily taking moderately high odds of significance at 49 to 1 (the 2-percent point) there is no significant difference among the 8-place averages of these 5 varieties. Within each of the 8 locations (table 2) there are only 2 instances in which any one of these 5 varieties is outyielded by any variety at *any* location by odds of 49 to 1. Wenholz 1 and Wenholz 2 are so surpassed at Experiment, Ga., by Wannop, 1 of these 5 highest. Thus, out of the 80 possible comparisons among these 5 highest varieties within locations, 2 showed significant differences—practically the theoretical expectancy at the 2-percent level. Still, *none* of these 5 was significantly lower than any *other* variety at any location. These comments apply only to yielding capacity, the characteristic probably of most importance. It is recognized, however, that among varieties of equal yielding ability some may be more sensitive to conditions affecting color, shape, or other qualities, thus making them definitely more desirable (or less desirable) in some locations than in others. Yielding capacity alone does not establish superiority.

Starch Content

It is common knowledge that yields of sweetpotato varieties differ from year to year and from place to place, but no report has been noted of a well-designed study that shows accurately the effect of season and place on starch content. Earlier studies by some of the authors of this circular and by others [16] showed marked differences in starch content among varieties, among years, and among places, but they were not conducted in such a manner that interactions between effects could be determined or the main effects determined accurately for a large number of varieties.

Varietal differences in starch content are of major importance, and efforts are being made to obtain new kinds with greater starch content as well as greater yielding capacity. Table 6 shows the percentage of

[16] See footnote 14.

TABLE 6.—*Mean starch content and calculated yields per acre of starch of 38 kinds of sweetpotatoes grown at 8 locations in 1940, 1941, and 1942* [1]

Variety or seedling	Beltsville, Md.		Blackville, S. C.		Experiment, Ga.		Tifton, Ga.		Meridian, Miss.		Laurel, Miss.		Baton Rouge, La.		Gilmer, Tex.		Mean	
	Content	Yield	Content	Yield	Content	Yield	Content	Yield	Content	Yield	Content	Yield	Content	Yield	Content	Yield	Content	Yield
	Percent	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*
Big-Stem Jersey	15.9	2,228	21.6	3,404	20.6	1,359	22.3	2,265	21.8	2,590	22.9	1,097	22.9	2,168	22.3	1,837	21.3	2,119
Director	21.5	3,629	26.4	4,995	27.0	2,614	26.5	3,417	25.2	3,695	29.9	3,289	28.6	4,700	24.4	4,027	26.2	3,796
Florida	21.7	2,675	25.4	3,038	25.7	1,903	25.7	3,019	26.1	3,524	27.5	2,690	25.4	3,886	25.9	3,438	25.4	3,022
Mameyita	19.4	2,923	21.8	2,001	21.4	1,595	24.3	2,464	21.9	2,913	23.9	2,647	22.9	4,047	21.5	2,950	22.1	2,693
Myers Early	20.6	2,957	24.7	3,188	23.4	1,693	25.5	2,402	23.3	1,984	27.0	2,065	28.0	4,095	22.7	3,512	24.4	2,737
Nancy Hall	21.1	3,105	25.1	2,723	25.4	1,883	23.9	2,417	22.6	2,190	24.6	2,385	26.2	4,151	23.5	3,260	24.1	2,765
North Carolina No. 1	19.8	3,388	21.5	1,931	21.4	1,517	22.8	2,982	21.5	2,242	23.9	2,267	23.7	4,346	21.4	3,485	22.0	2,770
Norton	21.8	3,223	25.8	2,968	26.3	1,743	26.7	2,741	25.7	3,067	28.4	2,173	28.4	4,287	25.2	3,424	26.0	2,953
Pierson	20.4	4,072	23.4	3,511	21.9	1,842	21.4	2,620	23.5	2,786	25.8	2,116	26.4	3,864	21.6	3,349	23.2	3,020
Porto Blanco	19.8	1,722	22.8	2,416	23.4	1,344	23.4	2,286	22.6	2,139	25.1	1,616	25.1	3,487	21.7	2,618	23.0	2,204
Porto Rico	19.6	3,079	21.4	2,228	20.7	1,426	23.2	2,540	21.8	2,963	24.4	1,973	22.7	4,090	20.0	2,637	21.7	2,617
Purple Stem Triumph	19.1	2,738	21.0	2,484	21.9	1,389	23.4	2,830	21.7	2,711	24.5	2,927	21.3	3,203	22.7	3,182	22.3	2,683
Red Bermuda	20.8	3,378	22.9	3,113	23.0	1,953	25.7	3,315	20.4	2,715	25.5	1,987	26.3	4,197	22.2	3,393	23.4	3,007
Red Brazil	21.7	3,551	25.0	1,952	25.0	1,739	25.3	2,354	24.8	2,461	25.8	1,730	26.5	4,113	24.0	3,558	24.8	2,682
Southern Queen	23.4	3,448	26.7	2,493	25.7	1,918	26.2	3,056	24.0	3,486	27.2	2,549	28.2	3,790	22.0	3,234	25.4	2,997
Triumph	23.1	3,458	26.7	2,943	23.9	2,065	24.0	3,498	24.8	3,741	25.9	3,006	24.4	3,576	22.9	3,721	24.5	3,251
Unit I Porto Rico	19.0	2,970	22.8	2,531	21.4	1,630	21.9	3,082	20.8	3,210	23.4	2,143	22.5	4,159	21.0	3,356	21.6	2,885
Wenholz 1	20.8	3,903	27.0	4,045	26.7	2,353	27.0	3,354	25.6	4,098	26.2	2,677	28.8	5,522	27.0	4,669	26.1	3,828
Wenholz 2	20.8	4,160	26.3	3,627	25.7	2,197	27.2	3,978	27.6	4,659	27.0	2,881	29.0	5,245	26.3	3,995	26.2	3,843
Wanmop	19.5	4,237	24.0	3,458	23.0	2,623	20.4	2,683	22.9	3,441	27.5	3,521	24.6	4,844	24.3	4,214	23.3	3,628
Yellow Strasburg	23.2	3,661	27.4	2,569	26.8	2,046	25.8	2,684	27.4	3,692	26.8	2,392	28.9	4,380	27.2	2,777	26.7	3,025
S-312	21.3	2,799	22.5	2,439	21.6	1,413	26.4	2,838	28.3	2,886	27.1	1,857	28.5	4,536	25.8	2,554	25.2	2,665
22437	22.1	2,838	26.1	2,706	25.9	1,534	27.5	2,189	27.3	2,915	27.1	1,737	28.0	2,941	24.4	2,144	26.1	2,376
24171	17.0	2,746	20.9	3,128	22.2	1,560	22.3	3,635	22.8	2,313	25.1	2,163	23.5	3,623	20.6	3,451	21.8	2,827
47442	19.2	2,764	21.2	2,554	24.0	1,627	24.2	2,450	22.3	2,602	25.3	2,036	22.7	3,219	21.6	3,023	22.6	2,534
47443	15.0	3,255	19.7	2,280	19.9	1,054	17.9	1,199	19.6	2,041	21.5	2,042	20.8	3,640	17.8	2,247	19.0	2,219
64377	22.0	2,778	25.2	2,232	26.6	1,456	25.3	2,623	25.8	3,152	27.5	2,288	28.1	4,134	24.1	2,439	25.6	2,638
85985	15.2	2,688	16.3	1,936	19.6	1,881	20.2	1,565	19.4	1,786	23.3	2,039	19.1	2,363	19.3	2,015	19.1	2,034
85986	22.2	3,426	25.6	2,868	23.2	1,446	25.1	1,978	26.8	2,802	26.3	1,791	28.4	3,993	23.7	2,532	25.2	2,604
021745	20.0	3,435	24.9	3,398	25.4	1,957	26.8	2,389	25.8	2,949	27.6	1,826	27.0	3,558	27.2	3,071	25.6	2,823
029878	20.4	3,211	24.9	2,546	25.5	2,118	23.3	2,172	27.9	3,422	25.6	2,427	[2] 26.3	[2] 4,085	23.8	4,160	24.7	3,018
029881	16.3	3,254	23.7	3,220	21.4	2,132	23.6	2,978	20.9	3,502	23.1	2,308	25.0	3,854	20.8	3,603	21.8	3,106
B-27	18.9	2,229	20.8	2,021	20.6	1,060	20.9	2,296	21.6	2,522	22.6	1,676	23.0	3,192	19.9	2,736	21.0	2,216
B-33	21.8	3,622	22.5	2,381	23.5	2,501	24.1	2,634	24.0	4,117	24.8	3,113	25.0	4,865	23.6	3,816	23.7	3,381
B-52	18.3	3,002	21.9	2,408	21.1	2,100	22.9	3,087	22.2	3,481	23.9	2,326	24.2	4,489	21.5	3,580	22.0	3,059
B-196	20.9	3,634	25.1	4,435	25.4	2,497	26.1	4,294	24.9	4,381	25.9	3,049	26.7	5,306	23.3	5,091	24.8	4,086
B-204	20.0	4,286	21.1	2,713	22.8	1,851	23.0	3,311	21.1	3,367	24.9	2,972	23.8	3,473	21.5	3,109	22.3	3,135
B-219	19.7	3,770	22.6	4,175	21.2	1,997	23.2	3,059	21.2	3,285	23.5	2,220	22.6	4,478	20.6	4,091	21.8	3,384
Place mean	20.1	3,217	23.5	2,870	23.4	1,816	24.1	2,755	23.6	3,048	25.5	2,316	25.4	3,997	22.9	3,271	23.6	2,911
Difference required for significance between varieties within places	1.9	881	1.9	960	3.4	524	3.1	866	2.4	1,058	2.6	883	2.2	876	2.2	931	.9	353

[1] Difference for significance between means of locations: Starch content, 0.4 percent; starch yield, 146 pounds.

[2] Calculated value; variety not grown.

starch and the calculated weight of starch produced per acre by each variety listed in table 2. It will be noted first that starch content differs far less among varieties, places, or years (table 7) than do the yields of roots (table 3). Furthermore, starch content does not fluctuate so much from unknown reasons or "uncontrolled" factors as do yields. The coefficients of variability for No. 1 and total yields, respectively, are 25 and 18 percent; for starch content only 6 percent. For estimated starch yield, however, the coefficient of variability is 19 percent, essentially the same as for total yield of roots.

Among varieties, years, and places the dry matter other than starch generally ranged from 8 to 10 percent of the fresh weight. The coefficient of correlation between starch and dry matter in several tests was 0.9 or higher, and the coefficient of regression of starch on moisture was about 0.97, with an error of estimate of 1.0 to 1.5.

Triumph is the variety being grown at present for manufacture of starch and is taken, therefore, as the standard in evaluating other sorts. The next to last column of table 6 shows the percentage of starch for varieties in the combined tests. Note that Triumph contained 24.5 percent starch, 0.9 percent, or barely significantly, more than the value of an average variety in these tests. Porto Rico, the most popular table variety in the South, contained only 21.7 percent, much less than an average variety in this table. Only 1 common variety of the so-called "dry-fleshed" type, Big-Stem Jersey, was included in the study, because that type is known to contain relatively little starch. It was among the lowest of this collection of sorts, with 21.3 percent starch. Nancy Hall, its synonym Myers Early, and Southern Queen, well-known table sorts of the "moist" type, showed starch contents similar to Triumph. Two old but now little grown sorts, Norton and Yellow Strasburg, were outstanding for their generally high starch content, 26.0 and 26.7 percent, respectively, both significantly higher than Triumph. Among the comparatively recent introductions from other lands 3 varieties from Australia are outstanding; Director, Wenholz 1, and Wenholz 2 all had more than 26 percent starch. Introduction No. 22437 from Japan also contained over 26 percent. Ninety-six determinations entered into each of the starch percentage figures given (duplicate determinations from 2 plots in each of 24 tests), permitting reasonable confidence in the differences that appear among the varieties.

The effect of place upon the starch content of sweetpotatoes may be of almost as much interest and practical importance as that of variety. The mean values for each location shown in table 6 are very striking. Roots from the northernmost location shown, Beltsville, Md., had 20.1 percent, much less starch than the 25.4 percent in those from Baton Rouge, La., the southernmost location. Crops from Laurel, Miss., averaged 25.5 and from the other locations approximately 23 to 24 percent starch. The reasons for these differences are not clear. Neither length of time from planting to harvest nor normal weather variations seem to account for them.

When all locations were averaged, there was no important difference in starch content from year to year (table 7), although the slightly lower figure for 1941, 23.1, was statistically significant as compared with 23.8 percent for 1940 and 1942. Yearly means for all locations are of little interest or value, but the differences among years at single locations are great and of much practical consequence. Table 7 shows that within most locations, mean starch content for all varieties combined varies from year to year by as much as 2 to 4 percent. For example, there was apparently one-sixth more starch per ton of roots in the Laurel crop of 1942 than in that of the preceding year; and about a sixth more at Beltsville in 1942 than in 1940. Laurel's lowest year mean, however, was higher than Beltsville's highest. Despite the highest variation from year to year at a single location, certain locations average significantly better than others. (Note the variances for starch content due to places and to years × places, shown in table 4.) Thus, it appears that a starch or feed-drying plant operating in the northern part of the sweetpotato belt would obtain a consistently lower yield of product per ton of raw stock than one processing the same varieties in the lower South.

TABLE 7.—*Mean starch content and calculated starch yields per acre of 38 kinds of sweetpotatoes at 8 locations for 3 years*

Place	1940		1941		1942		Mean	
	Content	Yield	Content	Yield	Content	Yield	Content	Yield
	Percent	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*
Beltsville, Md	18.4	2,937	20.0	2,343	21.8	4,371	20.1	3,217
Blackville, S. C	25.1	4,213	23.7	1,592	21.9	2,805	23.5	2,870
Experiment, Ga	25.4	2,001	22.3	1,324	22.6	2,124	23.4	1,816
Tifton, Ga	24.0	1,897	23.2	2,742	25.1	3,626	24.1	2,755
Meridian, Miss	22.2	1,776	24.9	2,789	23.8	4,578	23.6	3,048
Laurel, Miss	26.1	1,978	23.1	1,381	27.3	3,589	25.5	2,316
Baton Rouge, La	25.0	3,010	25.6	4,081	25.8	4,900	25.4	3,997
Gilmer, Tex	24.5	3,601	22.2	3,063	21.9	3,150	22.9	3,271
Mean, all places	23.8	2,677	23.1	2,414	23.8	3,643	23.6	2,911
Difference required for significance:								
Between places for all years							.4	162
Between years for all places							.3	99
Between years for 1 place							.8	292

Do these place and year effects appreciably upset the relative starch contents or ranking of sweetpotato varieties? The variances for interaction of place and of year with variety are significantly much smaller than those for variety alone. Thus, although place and year do not affect all varieties exactly alike (the interactions are significant with reference to "error"), the relative starch percentages among the varieties are rather consistently maintained. The high starch varieties remained high in all places and years and the low ones were low, although minor shifts in relation to one another occurred. Table 6 shows, for example, that only 4 cases can be found within locations in which Yellow Strasburg, Director, Wenholz 1, or Wenholz 2 is significantly lower in starch than any of the 34 other varieties. Porto Rico, one of the lowest, is on the average significantly better than only 2 other varieties in the list. Table 6 shows only 3 cases in which Porto Rico is significantly higher than any varieties in addition to the 2 that it exceeds on the average.

Weight of Starch Per Acre

Among the many hundreds of seedlings and varieties analyzed a very disconcerting tendency has been found for the most attractive and high-yielding sorts to be very low in starch. Conversely, the root yield and appearance of sorts having the highest percentage of starch usually turn out to be poor. For industrial or feed use a reasonably high starch content is necessary in the interests of manufacturing efficiency, regardless of yield; but yield of sweetpotatoes, of starch, or of other products per acre cannot be disregarded for convenience in processing. Profitable yields as well as desirable quality must be obtained if sweetpotatoes are to be used for such purpose. It is necessary, therefore, that the total weight of starch per acre be considered with reference to varieties, places, and years.

Tables 6, 7, and 4 (the order in which they will be referred to in this section) show the results of calculating the weights of starch produced per acre. The greatest mean weight of starch per acre, 4,086 pounds, was produced by B–196, the highest yielding variety but not the variety with the highest starch content. Its starch content was 24.8 percent, not significantly more than that of Triumph, although its starch yield was 835 pounds more. Yellow Strasburg, an old variety with the highest starch content in the test (26.7 percent), produced only 3,025 pounds of starch because of its indifferent yielding ability; Norton, another old variety, showing 26.0 percent starch, produced less than 3,000 pounds.

Some other varieties approaching the highest average yields of starch per acre were Wenholz 1 and Wenholz 2 with 3,828 and 3,843 pounds, respectively; Director with 3,796 pounds; and Wannop with 3,628 pounds, all four of them introductions from Australia. There are no significant differences in starch yield per acre among the four. These, together with B–196, all significantly outyielded Triumph in starch, and they are the only ones that did. A variety with high percentage of starch may produce a low yield of starch, but varieties so far observed that produce a high yield of starch per acre are generally much above average in starch content. Those with starch content significantly below the average of the group were always mediocre to low yielders of starch per acre, regardless of root yields per acre.

Table 7 shows the calculated yields of starch per acre by locations and years. The yields of starch are not closely correlated with the percentages by locations because of the very marked variations in yield of roots that are not closely correlated with starch content. Neither factor outweighs the other in obtaining a high yield of starch. Plantings at Laurel had the highest percentage of starch but next to the lowest weight per acre; at Experiment, percentage was average but weight was at the bottom of the list; and at Beltsville, despite the lowest starch percentage, the weight of starch was above average.

The year-to-year variation in starch yield was very large (table 4), especially within locations. There are strong indications that very dry seasons that hold root yields much below average also hold starch percentage and total dry matter below average. On the other hand, in a very wet year or an unusually high-yielding year starch content does not appear to be above or below average. From a practical standpoint, however, it is safe to say that for any given variety in a location the only way to get good yields of starch per acre is to get good yields of roots per acre. Although highly significant differences in percentage occur from year to year, they are outweighed by the effect of root yield in the determination of total weight of starch. Location must be kept in mind, too. Although the highest average root yields were obtained at Beltsville, starch weights per acre were only medium.

To what extent do high starch-yielding varieties maintain their relative superiority in different locations, despite the variations in yield level? Table 6 (see the group of four superior starch-yielding varieties: B-196, Wenholz 1, Wenholz 2, and Director) shows that there were only eight instances in which other varieties surpass the mean yield of those four by any margin whatever in any location; and in no instance are they significantly inferior. On the other hand, the mean of these varieties is superior to Triumph in all locations except Laurel and significantly so within two locations. B-196, the highest average yielder, exceeds Triumph at every location, Wenholz 1 and Director surpass it in all but two each, and Wenholz 2 in all but one. Similar consistency of behavior can be noted in most of the low starch producers; for example, Big-Stem Jersey is at the bottom of the list three times, near the bottom three times, and significantly below Triumph in seven of the eight locations. Porto Blanco and 85985 are other consistently low yielders.

Some few varieties, on the other hand, seem to yield significantly higher in some places than others, serving to complicate the task of evaluating varieties for adaptability to a wide range of conditions. For example, Red Brazil was significantly higher than Big-Stem Jersey at Beltsville, Baton Rouge, and Gilmer, while it was the opposite at Blackville. Thus, it is evident that 3-year tests at only two or three locations cannot safely filter out those varieties having truly wide adaptability, because of local or sectional superiorities of some varieties. The most important and encouraging fact indicated here is that very widely adapted varieties can be found that will yield consistently at a highly productive level. Furthermore, such varieties apparently can be equal or superior to the best of any of those that are adapted to only small sections. *In these tests no variety of apparent local or sectional superiority has been proved thus far to be conclusively more productive than the best widely adapted variety.*

RESULTS AT ONLEY, VA.

At Onley, Va., the 38 varieties were grown on soil heavily infested with the fusarium wilt (stem rot) organism. The last column of table 5 indicates roughly the relative susceptibility of the varieties to infection, but it does not reflect the severity of the disease. Of the percentage of plants infected, varying proportions died before harvest and those living until harvest showed widely different degrees of damage. Despite the attacks of wilt and the widely varying percentages of plants infected, Big-Stem Jersey, Mameyita, Myers Early, Porto Rico and its strains, Nancy Hall, and B-27 were the only varieties that appeared to have their yields seriously reduced by it. (Compare with yields shown in table 2.) In general, the relative yields of the 38 varieties grown at Onley were very similar to those at Beltsville, although the total yield level was somewhat lower and the yields of No. 1 grade were very much lower. Wannop, Wenholz 2, Pierson, 029881, B–204, and B–219 were outstanding as at Beltsville. B–196, however, appeared to have suffered somewhat from wilt. Thirty-one percent of the plants of introduction 029881 were infected with wilt; but the variety appeared to be damaged little, if any, by it, since it was second highest in total yield of all varieties. The poor showing of Big-Stem Jersey on wilt-infested soil is very noticeable.

The mean starch content of all varieties for 2 years at Onley is nearly identical with the 3-year mean at Beltsville and 0.9 percent lower than for the 1941 and 1942 mean analyses at Beltsville. This agrees with the earlier observation that sweetpotatoes grown in the more northerly sections tend to have a lower starch content than those grown in the lower South. Close comparisons among all the varieties and within varieties at Onley and other locations cannot be made because of the limited data from Onley. At the same time, the varieties analyzed in 2 years at Onley bear very nearly the same relation to one another in starch content as when grown at Beltsville and other locations. (See table 6.)

In calculated yield of starch per acre at Onley, Big-Stem Jersey, B–27, and Porto Blanco were the three lowest as at Beltsville, and among the four lowest at the eight locations combined. The five highest at Onley were Pierson, Wannop, B–204, B–196, and Wenholz 2; at Beltsville they were B–204, Wannop, Wenholz 2, Pierson, and Wenholz 1; for eight locations combined they were B–196, Wenholz 2, Wenholz 1, Director, and Wannop. Despite the lack of comparability of the Onley data, there is fair agreement among the low- and the high-yielding varieties at Onley and other places. In the intermediate range the relative ranks are much more variable. For the most part the varieties in this range are of secondary or minor interest, although they are of more practical value than the low-yielding group.

The more or less spotty inroads of disease in the tests at Onley were doubtless partly responsible for the very high error observed for yields of roots (table 5).

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