

2007 PROGRESS REPORT  
To  
North Carolina Sweetpotato Commission

TITLE: Sweetpotato Grower-Participatory Breeding Project Support

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DEPARTMENT: Horticultural Science

REPORT:

**Project Objective(s):** The objectives of the Sweetpotato Breeding and Genetics Program are: 1) to develop sweetpotato varieties for North Carolina growers that possess exceptional yield, appearance, quality, and disease and insect resistance characteristics; and 2) to conduct basic and applied breeding and genetics studies focused on identifying and incorporating traits of economic importance into sweetpotato germplasm and new cultivars. The specific objectives of the Grower-Participatory Breeding Project (GPBP) are to work collaboratively with growers, Extension Agents and Specialists to evaluate seedlings, and preliminary and advanced selections of our most promising breeding lines on-farm with the goal of rapidly selecting and developing new varieties.

**Project Cooperators**

Extension Personnel

Howard Wallace  
William Little  
Allan Thornton

Growers

Wayne E. Bailey Farms, Columbus County  
Jones Farms, Nash County  
Terrell and Johnny Williams Farms, Sampson County

**Project Summary:**

The Grower-Participatory Breeding Project has been in existence for ten years and we have two primary research objectives. First, we grow and select first-year seedlings on commercial farms. Second, we evaluate our most promising advanced lines on-farm so that growers can provide input on their commercial potential. Those that perform well can be rapidly increased by growers, and evaluated for field, storage and packing traits on a larger scale. 'Covington', released in 2005, is our first "graduate" of this system of breeding. NC99-573, an advanced line that is now being evaluated on-farm by several seed producers, has also passed through this system.

This collaborative effort has been very successful in that it has increased information exchange between growers, researchers and extension personnel. From a breeding perspective, it has also enabled us to better define our breeding goals and prioritize these based on input from growers. For growers, it has allowed us to demonstrate and explain how new cultivars are developed.

Table 1 provides a summary of the number of clones the GPBP has screened on-farm as part of the GPBP. To date, this project has resulted in the development of 36 advanced lines that are in various stages of evaluation, and ten breeding lines that are being used in our polycross breeding nurseries.

Roughly 30% of the true seed grown in our breeding program during 2007 were grown on three farms with the cooperation of growers, Extension Agents and Specialists. Field sites were located within commercial fields and the trials were treated in the same fashion as the commercial fields (fertilizer, pest control etc., except spacing) (Table 2). From 15,000 seedlings planted, 279 were selected for further evaluation, a rate of 1.8%, slightly above our long-term average. Soil types varied from site to site, though all sites were hit by drought. Our ability to evaluate the same lines under various conditions is one of the strengths of this project. All sites yielded selections that had better appearance than the check

varieties Beauregard and Covington.

Selection of single-hill seedling plots at harvest was based on the following subjective visual criteria: shape, flesh color, skin texture, relative yield, size distribution, root number, earliness, and observable diseases or defects. These selections will be planted in Clinton and Kinston in 2008 as unreplicated 25-hill plots for the second cycle of selection.

The second component of the GPBP is to evaluate promising breeding lines under commercial conditions. This year we planted 24 clones and 7 check lines at each location in unreplicated 50-100-hill plots at each location where the seedlings were grown. Notes on how they performed at each location are shown in Tables 3-5. These observations are combined with research station trial data and disease screening data to determine the potential of each as a cultivar. Covington and NC99-573 performed well across all of our GPBP trials.

Performance of the different clones varied significantly from farm to farm (Tables 3-6). Indeed, observing differences in clonal "performance" from site to site has been very useful for our breeding efforts because it allows us to select those clones that are most stable from site to site, and season to season. For an example of this see Table 6 which compares the yield and appearance ratings of all the clones tested across each of the three sites. Besides Covington, only four of the advanced clones performed reasonably well in all grower locations. Their descriptions are as follows:

**NC99-573** - This clone produces smooth skinned, rose-colored roots that are attractively shaped. Yield is high. Growing season is similar to 'Beauregard. May have rows of moderately prominent eyes. Lenticels may be fairly prominent in wet conditions. It is susceptible to root-knot nematodes, but like Beauregard they rarely cause cracking. Shapes and appearance very similar to Beauregard but shapes are more consistent.

**Disease Resistances:** Resistant to Fusarium wilt and Streptomyces soil rot, susceptible to root-knot nematodes.

**Status:** Grown in four commercial-scale production trials in 2007. Will be stored commercially this winter, and bedded commercially this spring. Eating quality appears to be good, canning and chipping quality is being tested. Virus indexed plants were used for the first time in 2006, and they performed well. A decision to release this clone will be made in the fall of 2008 depending on the storage, bedding and field performance this coming season. NC99-573 is a very good parent and we will continue to use it in our 2008 nurseries.

**NC03-066** - A copper to orange-skinned, orange-fleshed offspring of NC96-27 and is a product of the GPBP. It has strongly tubular shapes that tend to vary in length. Good appearance characteristics. Yield slightly off from Covington and Beauregard. Good plant producer.

**Disease Resistances:** Resistant to fusarium wilt, root knot nematodes and soil rot. No russet crack observed.

**Status:** Further trialing in 2008 on station and on-farm. May be used in nurseries in 2008.

**NC03-311** - A copper -skinned, dark orange-fleshed offspring of NC99-299, which is an offspring of Hernandez. It has blocky to elliptic shapes with good shape uniformity. Dry matter is 22% (Beauregard averages 18% in NC), which puts it in a suitable range for chipping and fry stock, especially coupled with the dark orange flesh and blocky shapes. Yield is good, though not as consistent as Covington. Downfall is susceptibility to soil rot and nematodes.

**Disease Resistances:** Resistant to fusarium wilt, but appears susceptible to root-knot nematodes and

soil rot. Needs further screening.

**Status:** Further trialing in 2008 on station and on-farm. In chipping and fry trials in winter 2007-08. Potential parent for improved chipping cultivars.

**NC04-198** - A rose-copper skinned, orange-fleshed offspring of NC96-27 and is another product of the GPBP. It has shapes similar to Covington, but is longer and not as consistent. Good appearance characteristics. High yield, but low dry matter (17%). Very good plant producer. Has occasionally set too many roots to size.

**Disease Resistances:** Resistant to fusarium wilt, and soil rot. Moderately susceptible to root-knot nematodes.

**Status:** Further trialing in 2008 on station and on-farm.

Please see the Variety Development Report for yield trial results of these clones and performance of other advanced clones in the program. Many other lines performed well in only one or two of the sites (Table 6), an indication that they are not broadly adapted.

When we are limited to testing on the research stations alone we typically do not see as many varied environments per season. Thus, the GPBP has enabled us to evaluate the performance of clones under a variety of stresses (e.g. drought, flooding, insect, disease and weed pressure) in a single year. If only a single evaluation site is available this process takes a few years, and we have to carry and increase lines that have serious weaknesses and this lengthens the time to release.

In addition to evaluating table-stock material in the on-farm trials, this year we included four purple-fleshed clones. None performed well, so while we have made progress in these groups we still have considerable work to do to bring them to the level of yield and appearance of the table-stock lines. This is not a particularly fair test for them since most are also high dry matter lines, which also makes them late since time is needed to produce the extra starch. The on-farm trials are dug when the three foot wide spaced seedling are ready, which is usually a bit early for the table-stock lines, and very early for higher dry matter material. Notes collected here will help us decide which purple-fleshed clones to use as parents for the next generation of crosses.

Our emphasis in 2008 will be on continuing the evaluation of advanced materials in multiple locations so we can identify widely adapted materials and advance them as quickly and under as many environmental conditions in a single year as possible. We will also be adding more specialty-types in these evaluations as they become available, including purple-fleshed lines and clones suitable for chips and fries.

## **Acknowledgements**

The continued support of the NC SweetPotato Commission is gratefully acknowledged. The exceptional technical expertise and assistance of Jarred Driscoll, Ben Winslow and Mark Clough, Research Technicians and Researcher with the sweetpotato and potato breeding programs, respectively is acknowledged. We also thank the research station staff at the HCRS, CCRS and CRS, and Peyton Peterson and Blake Bowen our summer helpers for excellent support, and Graduate Student Per McCord, for their assistance during the year.

Table 1. Number of sweetpotato seedlings planted and number selected over successive years (1998-2007) from on-farm GPBP tests.

Year	No. of true seed planted	No. of seedlings selected	No. of original seedlings remaining after 2 <sup>nd</sup> year	No. of original seedlings remaining after 3 <sup>rd</sup> year	No. of original seedlings at advanced evaluation stage	No. of original seedlings retained for breeding
2007	15000	279	----	----	----	----
2006	15000	204	24	----	----	----
2005	15000	330	37	14	----	----
2004	15000	186	18	8	7	2
2003	15000	157	24	11	9	2
2002	18000	251	10	7	3	4
2001	15000	153	22	5	1	0
2000	15000	303	24	7	5	1
1999	24000	260	47	10	7	1
1998	24500	358	22	9	4	2
Totals	171,500	2481	228	71	36	10

Table 2. 2007 Sweetpotato seedlings selected on farm.

Maternal parent	# selections	Maternal parent	# selections
<i>Williams Farms, seed from the 2006 SSR nursery</i>			
NC1880	14	NC00-720	6
NC96-61	14	NC02-350	14
NC97A-45	26	NC02-423	14
NC99-026	18	NC02-459	4
NC99-573	12	Ruddy	8
<b>Total</b>			<b>130</b>
<i>George Wooten, Wayne E. Bailey Farms, seed from 2006 SSR nursery</i>			
NC97A-45	7	NC02-350	14
NC99-026	5	NC02-423	9
NC99-573	3	NC02-459	13
NC00-720	1	Ruddy	1
NC01-156	20		
<b>Total</b>			<b>73</b>
<i>Jones Farms</i>			
<i>2006 Elite nursery</i>		<i>2006 SSR nursery</i>	
NC96-61	4	NC96-61	2
NC97-433	6	NC99-573	13
NC99-524	3	NC02-350	12
NC99-573	5	Ruddy	8
NC01-214	10	Tib 4	13
<b>Total</b>			<b>76</b>
<b>On Farm Grand total</b>			<b>279</b>

Table 3. 2007 On Farm 1 Trial, Columbus Co. - Trait Data. Please see Keys to Tables section at the end of this report for descriptions to the abbreviations.

CLONE	MAT	YLD	L/D	SKC	SKT	FL	EYE	LEN	SH	SHV	APP	Comments
B94-14 G2	E	7	3.5	rs	ms	3	7	7	3,4,7	4	5	^yld, ^MSH
Car. Ruby	ML	7	3	red	ms	3	7	7	3,4	4	4	~SG, ^MSH
Covington												
G2	EM	7	2.5	cu rs	ms	3.25	7	7	3,6	6	6	AT, g sz dist
Evangeline	ML	7	4	rs	sm	4	7	7	3,4,7	4	4	^L, IRR
Hernandez												
G2	LM	7	3	cu or	ms	4	6	7	3,4	7	6	~SPR, ~LE
99-573 G2	EM	7	3	rs	sm	3	6	7	3	7	7	~SPR, ^PD
02-350	ML	7	3	cu rs	sm	3.25	8	8	3,4	6	6	^rts, ~T
02-423	E	7	2.5	lt cu	ms	3.25	7	7	6,3	5	6	chky, T, ~SPR
03-066	L	6	4	cu	ms	3.25	7	7	4	7	5	AT, ~T, L
03-089	EM	8	3.5	red	ms	3.5	6	8	3,4,7	5	5	L, ~CRK
03-114	ME	6	3.5	rs	sflk	3	7	7	3,6	5	4	RSK, var hills
03-239	M	7	3	cu or	sm	3.25	8	8	6,3	7	6	~STR, ~SPR
03-311	L	7	3.5	cu or	ms	4	7	7	3,4	6	5	AT, L
03-372	ME	6	3	dk rs	sm	3.25	7	7	3,7	6	3	^VN, D, p sh
03-380	E	7	2.5	rs	sm	3	6	7	3	5	5	g sz dist
03-395	M	6	3	rs	sm	3	7	7	3	4	4	^T, CRK, AT, D
04-011	EM	7	2.5	cu	sm	3.25	5	7	6,3	6	6	^SPR, ~CRK, BL
04-069	E	7	2.5	lt cu	sm	3	5	7	3,6	7	7	^sz dist, ~SPR, ~YCR
04-090	M	7	3.5	rs	sm	2.75	8	8	3,4	7	5	AT
04-165	L	6	3.5	rs	sm	2.75	6	7	3	5	4	^rts, p sh
04-197	E	7	2.5	lt cu	sm	2.75	6	7	6,3	7	6	BL, ~CRK
04-198	M	7	3	rs	sm	3	8	8	3,6	6	5	AT, 20%L
04-383	ML	6	3.5	pi	sm	1.5	8	8	3,4	7	5	~T, ^VN, AT
04-468	E	7	3.5	rs	sm	3.25	6	7	3,4,7	6	5	^T, ^AC, L
04-531	ML	6	3.5	rs	sm	3	6	7	4	7	5	L, TP
NC413	L	4	4	pur	ms	P2	6	7	4	5	4	L, late
NC415	L	2	3	pur	sm	P3	5	7	3	5	2	^AT, ^^junk, ^2 <sup>0</sup> R
Pur04-069	L	2	3	pur	sm	P3	---	---	3	---	1	no roots, ^AT few
Pur04-079	E	5	3.5	pur	sm	P2	7	7	3,6	4	3	rts, ~SPR, B
Pur04-083	L	4	5	pur	sm	P2	7	7	3,4	7	3	^LG, ^VN, L
Pur04-108	L	4	4	pur	sm	P2	7	7	3,4	6	4	L, T, AT

Comments: Drought stressed field. Tendency for long roots and a lot of curved roots. Good test for drought stress. Covington, Hernandez, NC99-573 and NC04-069 had the best overall appearance.

Table 4. 2007 On Farm 2 Trial, Sampson Co. - Trait Data. Please see Keys to Tables section at the end of this report for descriptions to the abbreviations.

CLONE	MAT	YLD	L/D	SKC	SKT	FL	EYE	LEN	SH	SHV	APP	Comments
B94-14 G2	M	7	4	rs	ms	3.25	7	7	3,4	4	4	L,IRR
Car. Ruby	not rated											
Cov G2	M	7	2.5	cu rs	ms	3	7	7	3,6	7	7	~CV,~TS ^^L,^MSH, ^#rts,^TS
Evangeline Hernandez	L	7	3.5	rs	ms	3.25	7	7	3,7	3	4	
G2	L	7	3	cu or	ms	3.5	6	7	3,4	6	6	~T,~SPR,~TS
99-573 G2	ME	8	2.5	rs	sm	3.5	7	7	3,6	7	8	~SPR ~TS,~VN, ~MSH,BRD T,~SPR,CV,T P,BRD ^^TS, ~v nice,BRD
02-350	M	7	3	rs	sm	3.25	7	7	3,4	4	5	
02-423	ME	8	3	lt rs	sm	3	7	7	3	7	5	
03-066	M	7	3	cu or	sm	3	6	6	3,6	6	6	
03-089	Plants not available											
03-114	Plants not available											
03-239												D-RC ^rts/hill, nice, RC?
03-311	L	7	3.5	cu or	sm	3.5	7	7	3,4	7	7	
03-372	Plants not available											
03-380	ME	7	2.5	cu	sm	3.25	8	8	3,2	5	5	~ESC,~AC,~T P,mix sz D-RC ^SPR,^T,~TS, n sz dist
03-395												
04-011	EM	8	2.5	cu	ms	3	7	7	3,6	7	6	
04-069	ML	4	2.5	lt cu	sm	3.25	6	6	3,2,7	4	3	
04-090	ML	6	4.5	pi	sm	3.25	7	7	3,4	6	4	too L,BRD
04-165	L	4	4	rs	ms	3	6	6	4,7	3	3	^TS,RC?,D ^TS,^CRK, ^#rts ~ESC,AT, ^#rts/hill
04-197	M	7	4	cu or	sm	3.25	7	7	3,4	6	5	
04-198	L	7	3	lt cu	sm	3	7	7	3,6	6	6	
04-383	ML	7	2.5	rs	sm	2w/o	6	7	3,6	6	7	BON,~T D-RC
04-468												
04-531	M	6	2.5	rs	ms	3.5	7	7	3,4,2	3	4	^CV,^sh var,D
NC413	ML	6	4.5	pur	ms	P3	7	7	3,4	7	5	~AT AT,~SPR, ^MSH
NC415	L	6	3	pur	ms	P2	7	7	3	4	3	
Pur04-069	ML	6	1.5	pur	ms	P3	7	7	2,3	5	4	^VN,AT,^T
Pur04-079	EM	7	2.5	pur	ms	P1 nu	7	7	3	4	3	L AT, few rts ~SPR,~VN, ~LG,B
Pur04-083	L	7	4	pur	ms	P2	7	7	3,4	6	4	
Pur04-108	L	4	4	lt pu	sm	P1	7	7	4,7	6	3	D-RC

Comments: Very sandy site, suffered significant drought stress. Deep sandy soils resulted in long roots and low yields. Strong test for tendency to produce long roots.

Table 5. 2007 On Farm 3 Trial Nash Co. - Trait Data. Please see Keys to Tables section at the end of this report for descriptions to the abbreviations.

CLONE	MAT	YLD	L/D	SKC	SKT	FL	EYE	LEN	SH	SHV	APP	Comments
B94-14 G2	M	6	3.5	rs	sflk	3.25	8	8	3	5	5	~CV,~CR ~CR,~MSH,~ SPR
Car. Ruby Covington G2	M	6	3	rs	sm	3	7	7	3	6	4	~CV
Evangeline Hernandez G2	M	7	2.5	rs	ms	3.5	8	8	3	6	6	~SPR,mx sh ^SPR,~L MSH,~PI
99-573 G2	ME	8	3	rs	sm	3	6	7	3	8	8	~SPR
02-350	L	6	3.5	rs	ms	3	7	7	3,6	5	5	~Inf LE ^^SF,^CR,~sp
02-423	ME	6	1.5	lt rs	sm	3	7	6	3,2	4	3	r
03-066	L	6	2	cu or	flk	3.25	7	6	6	7	7	~TS
03-089	L	5	3	rs	ms	3	7	7	6,3	5	5	^rt/hill,~mx sz
03-114	L	4	3.5	rs	flk	3.5	7	6	3,7	4	3	^MSH,~SPR D-RC
03-239												
03-311	L	6	3	lt cu	ms	3	8	8	3,6	7	7	^rts/hill
03-372	L	5	2.5	cu or	sm	3.25	7	7	3,6	7	6	~SPR ~CR,~mx colors,~TP
03-380	M	6	2.5	rs	sm	3	6	7	3	5	4	D-RC ~SPR,T,~Cov
03-395												
04-011	LM	5	2	cu	ms	3.5	6	7	6,2	6	5	.
04-069	M	7	3	lt cu	sm	3	7	7	3	6	5	^TP,mx sz
04-090	M	7	3.5	rs p	sm	3	7	6	3	5	5	SPR,~LG
04-165	ML	6	3	red	ms	2.75	6	7	3,6	7	6	mx sz dist
04-197	ML	6	2.5	rs	sm	2.75	7	6	6,3	6	5	^CV ~CV, mx color hills
04-198	E	7	3	rs	ms	3	7	6	6,3	7	7	
04-383	L	5	3	red	sm	1.75	6	6	3,4	5	4	~SPR,~MSH D-RC
04-468												
04-531	ML	6	3	rs	ms	3	7	5	3	5	5	^SPR,~VN,~P I,^^LE ^SPR,^VN,
NC413	L	4	4	pur	ms	P2	5	7	3	5	3	few rts
NC415	L	3	2	pur	ms	P3	7	7	7	4	2	few rts,^AT
Pur04-069	M	6	3	pur	sm	P3 u	7	7	3	6	4	^VN,~SPR,AT ^CR,~SPR,^ MSH,AT
Pur04-079	M	4	3.5	pur		P2 nu	6	7	3,7	4	3	low#rts ^VN,~int
Pur04-083	L	3	4	pur	ms	P1 nu	7	7	3	5	3	disc,~SPR ~SPR, low#fb
Pur04-108	L	5	4.5	pur	sm	P2 u	7	7	6,3	7	6	rts

Comments: The trial was in a field that received very little rain and grew very little during the summer. A strong test for drought tolerance. Covington and NC99-573 had the best appearance in the field, considerably nicer than Beauregard and almost everything else in the trial.

Table 6. 2007 On Farm Trial Appearance and Yield ratings for all three sites.

CLONE	Appearance rating				Yield rating			
	Farm 1	Farm 2	Farm 3	Avg	Farm 1	Farm 2	Farm 3	Avg
<b>B94-14 G2</b>	<b>5</b>	<b>4</b>	<b>5</b>	<b>4.7</b>	<b>7</b>	<b>7</b>	<b>6</b>	<b>6.7</b>
Carolina Ruby	4	NA	4	4	7	NA	6	6.5
<b>Covington G2</b>	<b>6</b>	<b>7</b>	<b>7</b>	<b>6.7</b>	<b>7</b>	<b>7</b>	<b>7</b>	<b>7</b>
Evangeline	4	4	6	4.7	7	7	7	7
Hernandez G2	6	6	5	5.7	7	7	6	6.7
<b>99-573 G2</b>	<b>7</b>	<b>8</b>	<b>8</b>	<b>7.7</b>	<b>7</b>	<b>8</b>	<b>8</b>	<b>7.7</b>
02-350	6	5	5	5.3	7	7	6	6.7
02-423	6	5	3	4.7	7	8	6	7
03-066	5	6	7	6	6	7	6	6.3
03-089	5	NA	5	5	8	NA	5	6.5
03-114	4	NA	3	3.5	6	NA	4	5
03-239	6	RC	RC		7	RC	RC	
03-311	5	7	7	6.3	7	7	6	6.7
03-372	3	NA	6	4.5	6	NA	5	5.5
03-380	5	5	4	4.7	7	7	6	6.7
03-395	4	RC	RC		6	RC	RC	
04-011	6	6	5	5.7	7	8	5	6.7
04-069	7	3	5	5	7	4	7	6
04-090	5	4	5	4.7	7	6	7	6.7
04-165	4	3	6	4.3	6	4	6	5.3
04-197	6	5	5	5.3	7	7	6	6.7
04-198	5	6	7	6	7	7	7	7
04-383	5	7	4	5.3	6	7	5	6
04-468	5	RC	RC		7	RC	RC	
04-531	5	4	5	4.7	6	6	6	6
NC413	4	5	3	4	4	6	4	4.7
NC415	2	3	2	2.3	2	6	3	3.7
Pur04-069	1	4	4	3	2	6	6	4.7
Pur04-079	3	3	3	3	5	7	4	5.3
Pur04-083	3	4	3	3.3	4	7	3	4.7
Pur04-108	4	3	6	4.3	4	4	5	4.3
Means	4.7	4.9	4.9	4.8	6.1	6.5	5.6	6.1

NA – plants not available

RC – russet crack



## Keys to Tables

**Storage root data:** **MAT**=maturity E=early, M=mid and L=Late; **DM**=percentage dry matter; **L/D**=length/diameter ratio; **SKC**=skin color clr=clear cu=copper, lt=light, or=orange, pi=pink, pu=purple, rd=red, rs=rose, tn=tan wh=white; **SKT**= skin texture, m fl= moderate flakiness of skin, l fl= light flakiness to skin, ms=moderately smooth, sm=smooth; **FL**=flesh color (0-5 scale where 0=pure white, 1= cream, 2=yellow, 3= medium orange, 4=deep orange, 5= very deep orange; **EYE**=eyes(0-9); **LEN**= lenticels (0-9); **SH**=Shape (see diagram); **SHV**=shape variability(0-9); **APP**=overall appearance (0-9). All 0-9 scales go from low or poor to high or good.

**Comment codes:** **AC**=air cracking; **AT**=tough attachment; **B**=bumpy shapes; **BL**=blocky shapes; **BON**=Boniato type; **BRD**=breeding only; **BSR**=bacterial soft rot; **CR**=cracking; **CRK**= crooked shapes; **CS**=circular spot; **CV**=skin color variation end to end; **D**=drop; **ESC**=Early season cracking; **EY**=deep eyes; **FB**=fleabeetle damage; **FS**=Fusarium root rot; **G**=Geotricum; **GR**=grooves; **HC**=horizontal constrictions; **ID**=unspecified insect damage; **IR**=insect resistance; **IRR**=irregular; **JL**=jumbo's for length; **L**=long; **LE**=lenticels; **LG**=longitudinal grooves; **LR**=Lateral rings; **LT**=latex; **MSH**=misshappen roots; **NS**=nice shapes; **OV**=ovate or pear shapes; **PD**=Plectris damage; **PI**=pimples (0-9); **PN**=pencil roots; **PP**=pulled plants; **R**=rodent; **RC**=russet crack; **RG**=restaurant grade; **RH**=root hairs; **RKN**=root-knot nematodes; **RND**=round; **RSK**=rough skin; **RT**=rot; **SC**=scurf; **SD**=skin discoloration; **SF**=surface Fusarium; **SG**=string roots; **SH**=sheen; **SK**=skinning; **SO**=souring; **SPR**=sprouts; **SR**=soft rot; **SS**=stays short; **SSR**=streptomyces soil rot; **STR**=striations; **T**=tails; **TP**=tapered roots; **TS**=tea staining; **VN**= veins; **WB**=whitefringed beetle; **WG**=white grub; **WW**=wireworm; **YCR**=yellow cortical ring; **YLD**=yield; **2°R**=secondary roots.

^ = lots, ~ = moderate, ↓ = little or poor

(Rating scale: 0 = very severe to 9 = absent)

## Shapes

