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Clearwater Russet: A Dual-Purpose Potato Cultivar with Cold Sweetening Resistance, High Protein Content, and Low Incidence of External Defects and Sugar Ends

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Abstract Clearwater Russet is a medium-late maturing, russet-skinned, potato cultivar suitable for processing or fresh pack. It is notable for having a low incidence of external defects that contributes to its high U.S. No 1 yield relative to the dual-purpose industry standard, Russet Burbank. Clearwater Russet also maintains low glucose concentrations in its tubers during long-term storage making it an exceptional processing variety. With its low incidence of sugar ends and cold-induced sweetening resistance, Clearwater Russet can be stored at a temperature of 7.2°C for up to 250 days without the need for reconditioning; fry color from this storage regime is consistently ≤1.0 (USDA Fry Color Scale). This cultivar is also notable for its high tuber protein content, which was 33% greater than that of Russet Burbank. In full-season trials conducted over a 3-year period in California, Colorado, Idaho, Oregon, and Washington, Clearwater Russet had total yields slightly lower than Ranger Russet and Russet Burbank, but averaged 1% and 33% higher U.S. No. 1 yields, respectively, across all states. Average specific gravity of Clearwater Russet is comparable to Ranger Russet and significantly higher than Russet Burbank.

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Clearwater Russet is resistant to potato virus X (PVX) and tuber late blight and is moderately resistant to Verticillium wilt, common scab, and the common strain of potato virus Y (PVY^O). Symptoms of infection with two necrotic strains of PVY were not observed in tubers of Clearwater Russet or Russet Burbank, but were observed in Ranger Russet. Blackspot bruise reaction for Clearwater Russet is less pronounced than for either Ranger Russet or Russet Burbank. The incidence of hollow heart in Clearwater Russet is intermediate between Ranger Russet and Russet Burbank. Internal brown spot has been noted as a problem for Clearwater Russet in the Columbia Basin of Oregon, but has not been observed as problematic in other growing regions. Clearwater Russet was released in 2008 by the USDA-ARS and the Agricultural Experiment Stations of Idaho, Oregon, and Washington, and is a product of the Pacific Northwest Potato Variety (Tri-State) Development Program.

Resumen Clearwater Russet es una variedad de madurez de intermedia a tardía, de piel corchosa, tanto para proceso como para consumo en fresco. Es notable por tener una baja incidencia de defectos externos que contribuye a su alto rendimiento de US No. 1, en relación con el estándar de Russet Burbank de la industria para doble propósito. Clearwater Russet también mantiene bajas concentraciones de glucosa en sus tubérculos durante almacenamiento por largos períodos haciéndola una variedad excepcional para procesamiento. Con su baja incidencia de azúcares finales y su resistencia al endulzamiento inducido por frío, Clearwater Russet puede almacenarse a temperaturas de 7.2°C por hasta 250 días sin necesidad de reacondicionamiento; el color de freído con este régimen de almacenamiento es consistentemente ≤1.0 (Escala de Color de Freído USDA). Esta variedad también es notable por su alto contenido proteico del tubérculo, que fue 33% mayor que el de Russet Burbank. En ensayos de toda la temporada que se desarrollaron en un período de tres años en California, Colorado, Idaho, Oregon, y Washington, Clearwater Russet tuvo rendimientos totales ligeramente abajo que Ranger Russet y Russet Burbank, pero promedió 1% y 33% más altos rendimientos de US No. 1, respectivamente, en todos los estados. El promedio de la gravedad específica de Clearwater Russet es comparable al de Ranger Russet y significativamente mayor que el de Russet Burbank. Clearwater Russet es resistente al virus X de la papa (PVX) y al tizón tardío de tubérculo, y es moderadamente resistente al marchitamiento por Verticillium, a la roña común, y a la variante común de virus Y de la papa (PVY^0). No se observaron síntomas de infección con dos variantes necróticas de PVY en tubérculos de Clearwater Russet o Russet Burbank, pero sí se vieron en Ranger Russet. La reacción de manchas oscuras por golpes para Clearwater Russet es menos pronunciada que para Ranger Russet o Russet Burbank. La incidencia de corazón hueco en Clearwater Russet es intermedia entre Ranger Russet y Russet Burbank. Se ha notado que la mancha café interna es un problema para Clearwater Russet en la rivera del Columbia de Oregon, pero no se ha visto como problemático en otras regiones de cultivo. Se liberó Clearwater Russet en 2008 por el USDA-ARS y por las estaciones experimentales de Idaho, Oregon, y Washington, y es un producto del Programa de Desarrollo de Variedades de Papa del Noroeste del Pacífico (Tri-State o tres estados).

Keywords *Solanum tuberosum* · Variety · Breeding · Processing

Introduction

Clearwater Russet is a product of the cooperative Pacific Northwest Potato Variety Development Program, comprised of the USDA-Agricultural Research Service and the Agricultural Experiment Stations of Idaho, Oregon and Washington. Clearwater Russet originated from a hybridization made by J.J. Pavek in 1995 between the potato cultivar Bannock Russet and the breeding clone A89152-4 (Fig. 1), and was first grown and selected in the field at Aberdeen, Idaho in 1997 where it was given the clonal designation AOA95154-1. The "AOA" breeding clone designation indicates that true potato seed originating from Aberdeen ("A") was sent to the Oregon potato breeding program for production of greenhouse seedling tubers ("AO"), with subsequent selection in the field in Aberdeen ("AOA") of Clearwater Russet from Oregon seedling tubers.

Potato varieties in the pedigree of Clearwater Russet (Fig. 1) include Bannock Russet (Novy et al. 2002), Butte (Pavek et al. 1978), Nooksack (Hoyman and Holland 1974), Norgold Russet (Johansen 1965), Ranger Russet (Pavek et al. 1992), Targhee (Pavek et al. 1973), and the red-skinned Viking (Johansen et al. 1963).

Clearwater Russet was evaluated as a 12-hill selection in 1998, and from 1999 to 2002 in replicated yield trials in Idaho. Clearwater Russet was entered in the Tri-State Variety Trials in Idaho, Oregon, and Washington in 2003 and 2004, and subsequently advanced to the Western Regional Potato Variety Trials where it was evaluated in full-season trials in California, Colorado, Idaho, Oregon, and Washington in 2005 through 2007. Subsequent seed increases and commercial trials of Clearwater Russet were conducted in Idaho, Oregon, and Washington.

On the basis of its attractive tubers, high U.S. No. 1 yields and protein content, cold-induced sweetening resistance, and low incidence of sugar ends, the decision was made by the

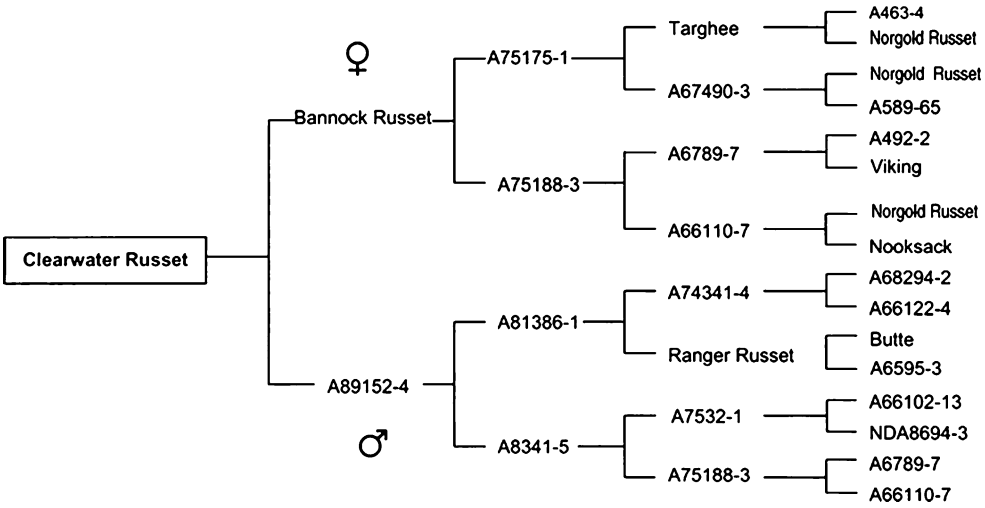

Fig. 1 Pedigree of clearwater Russet

Pacific Northwest (Tri-State) Potato Variety Development Program Committee to release Clearwater Russet. The "Clearwater" portion of the name references the Clearwater River that traverses the state of Idaho. Release documents for Clearwater Russet were completed in 2008.

Varietal Description

Plant and tuber descriptions of Clearwater Russet were obtained from field evaluations conducted at Aberdeen, ID unless noted otherwise.

Plants (Fig. 2a and b)

Growth habit: Medium sized, semi-erect vine expressing medium-late maturity. Vine architecture is open with stems partially visible. *Stems*: Moderately thick, medium green with slight red-purple anthocyanin pigmentation, and weakly prominent wings (<2 mm wide). *Leaves*: Medium-sized, green color (Royal Horticulture Society Color Chart, RHSCC yellow-green146B), with an open silhouette, and moderate red-purple anthocyanin pigmentation on the petioles and midribs. *Terminal leaflets*: Medium ovate shape with an acuminate tip and acute base; moderately wavy margins; average length 74 mm, width 42 mm (average of 80 mid-canopy leaflets). *Primary leaflets*: Range of three to five pairs with an average of 4.0 pairs; medium ovate with an acuminate tip and obtuse base. *Secondary leaflets*: One to five pairs, average of 3.6 pairs. *Tertiary leaflets*: None to 5 pairs, average 1.9 pairs. *Stipules*: Medium sized non-clasping

Flowers (Fig. 2c)

The number of inflorescences range from two to twelve per plant (average of 5.3), with an average of 10.2 florets per inflorescence. *Buds*: Anthocyanin pigmentation is slight and purplish-red in color. *Corolla*: stellate shape; purple with white tips (RHSCC purple 76A on the inside surface, purple 76B on the outside), medium-sized, averaging 36 mm diameter as measured from corolla tips. *Anthers*: yellowish-orange (RHSCC yellow-orange15A) arranged as a loose, pear shaped cone. *Stigma*: capitate, yellowish-green (RHSCC yellow-green146B). *Pollen*: Production of fertile pollen with success as a male parent. *Berries*: spherical, medium green, with moderate berry production in the field.

Light Sprouts (Fig. 2d)

Ovoid shape; tip is green with a semi-open growth habit and medium pubescence; base of sprout shows moderate purplish-red pigmentation; bud scales are closed and are moderately hirsute; moderate number of large root initials.

Tubers (Fig. 2e)

Oblong to long; similar in shape to Russet Burbank, but an average of 11 mm shorter than Russet Burbank; slightly flattened to medium thick; mean length 124 mm, range 91–178 mm; mean width 67 mm, range 54–80 mm; mean thickness 57 mm, range 45–73 mm; average tuber weight, 276 g (average of 80 tubers). *Skin*: Brown (RHSCC grayed-orange165B) with a medium russet pattern. *Eyes*: shallow; slightly prominent eyebrows; evenly distributed; medium number of eyes per tuber, mean 18, range 11–27. *Flesh*: light cream colored (RHSCC yellow-white 158B); slightly prominent pith region. *Dormancy:* 3 years of storage trials with no application of sprout inhibitors were conducted. The tuber dormancy of Clearwater Russet averaged 58 days less than Russet Burbank across three storage temperatures. Average tuber dormancies for Clear-

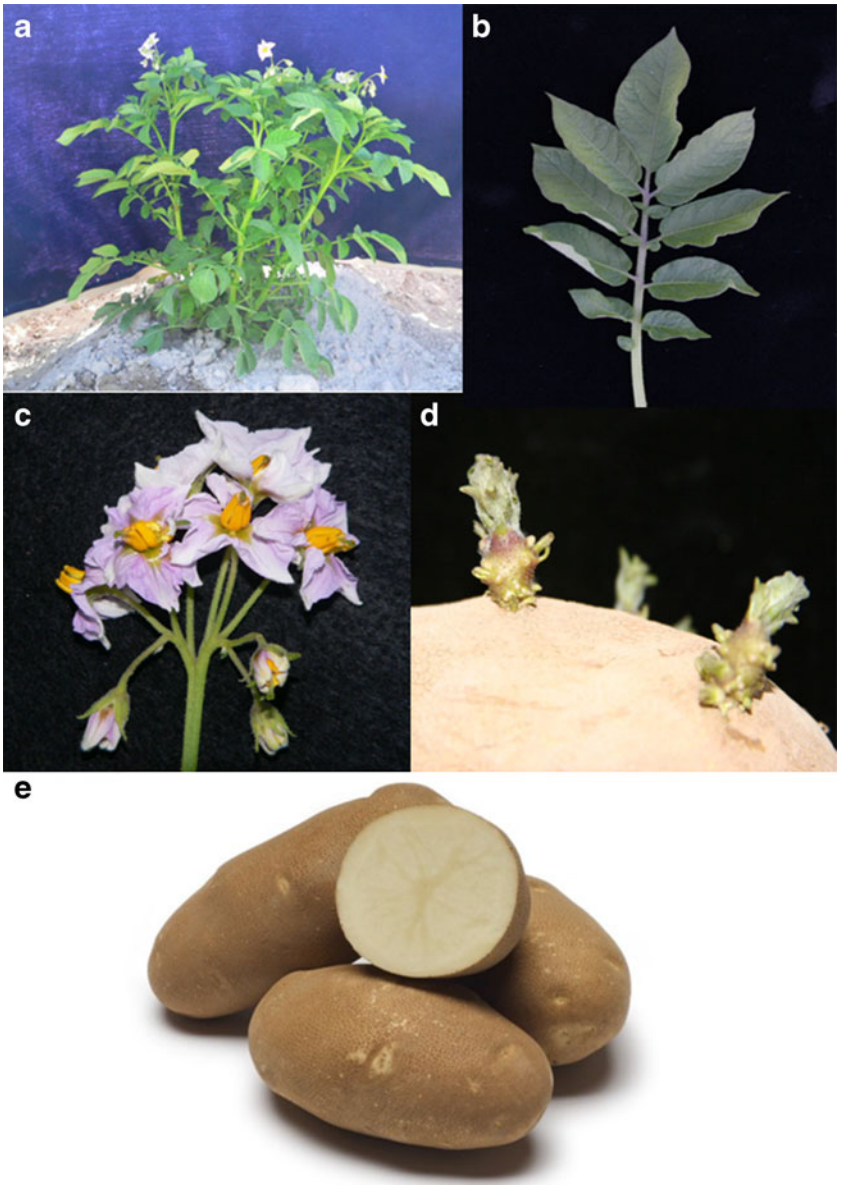

Fig. 2 Clearwater Russet: **a** plant, **b** leaf, **c** inflorescence, **d** light sprouts on tuber, and **e** external and internal tuber appearance

water Russet were 110, 90, and 85 days after harvest (DAH) at storage temperatures of 5.6, 7.2, and 8.9°C, respectively. Russet Burbank tuber dormancies at the same storage temperatures were 175, 155, and 130 DAH, respectively. Duration of dormancy was defined as the number of days from harvest until 80% of potatoes had at least one sprout ≥5 mm in length.

Agronomic Performance

Total yield of Clearwater Russet did not significantly differ from standard varieties in seven full-season trials conducted at Aberdeen and Kimberly, Idaho; sites located within the commercial potato production regions of southern Idaho (Table 1). However, U.S. No. 1 yield and percent U.S. No. 1 yield (United States Standards for Grades of Potatoes 1997) of Clearwater Russet significantly exceeded Russet Burbank by 12.5 t/ha and 21% respectively; Ranger Russet was comparable to Clearwater Russet for U.S. No. 1 yield and percentage No. 1 yield (Table 1). Clearwater Russet and Ranger Russet had similar tuber specific gravities, with both being significantly higher than Russet Burbank (Table 1). Tuber size distribution of Clearwater Russet was comparable to Russet Burbank and Ranger Russet except for having a greater percentage of tubers in the 114–169 g range relative to Ranger Russet (Table 1). Tuber defects were

Table 1 Average total yield, U.S. No. 1 yield, percent U.S. No. 1, specific gravity, tuber size distribution, French fry color, and percentage of sugar ends of Clearwater Russet, Ranger Russet, and Russet Burbank from seven full-season yield trials (125–135 days) conducted at Aberdeen and Kimberly, ID from 1999 to 2002

Cultivar	Yield (t/ha)		% No. 1	Specific Gravity[a]	Tuber size distribution as percent of total yield					Fry color[b]		Fry sugar ends[c]
	Total	U.S. No. 1			>341g	170–341g	114–169g	<114g	Cull	4.4°C	7.2°C	7.2°C
Clearwater Russet	51.2a[d]	43.3a	84a	1.085a	28ab	41a	16a	9a	6a	1.9a	0.4a	11a
Ranger Russet	53.4a	41.3a	78a	1.087a	35a	36a	7b	5a	17ab	2.8b	1.0b	24a
Russet Burbank	49.6a	30.8b	63b	1.075b	21b	30a	11ab	10a	28b	3.0b	1.1b	19a
LSD (0.05)	n.s.	7.1	9.6	0.005	14.0	n.s.	8.6	n.s.	13.7	0.81	0.50	n.s.

[a] Specific gravities were determined using the weight-in-air, weight-in-water method within 1 month of harvest

[b] French fry scores rated using USDA standards, with 0=light and 4=dark. A rating ≤2.0 is an acceptable score. Tubers were evaluated following 3–6 months storage at 4.4 or 7.2°C

[c] Percentage of fries with sugar ends following storage at 7.2°C

[d] Mean values followed by the same letter are not significantly (n.s.) different from one another ($P<0.05$) based on Tukey's test

significantly lower for Clearwater Russet than for Russet Burbank, with 6% cullage relative to Russet Burbank at 28% (Table 1).

Clearwater Russet also was evaluated over a 5 year period in trials conducted in Idaho, Oregon, and Washington (Table 2). Total yields of Clearwater Russet were comparable to Ranger Russet and Russet Burbank in all three states. However, U.S. No. 1 yield of Clearwater Russet consistently exceeded that of Russet Burbank at all locations, averaging 19.4 t/ha higher yields across all sites. Clearwater Russet also exceeded the U.S. No. 1 yield of Ranger Russet at Kimberly, Idaho and Hermiston, OR, with comparable U.S. No. 1 yield at Aberdeen, Idaho, and lower U.S. No. 1 yield at Othello, Washington. Among the three varieties, the percentage of total yield that could be categorized as U.S. No. 1 yield was highest for Clearwater Russet at all locations, with the exception of Othello, Washington where Ranger Russet exceeded Clearwater Russet. Specific gravities of Clearwater Russet significantly exceeded Russet Burbank at all locations and were comparable or higher than those of Ranger Russet.

In 3 years of evaluations in the Western Regional Potato Variety Trials (Table 3), Clearwater Russet had lower total yield, but a higher U.S. No. 1 yield and percentage of U.S. No. 1 relative to Ranger Russet and Russet Burbank, when averaged across all nine locations. While total yield and associated rankings among the three varieties varied at each location, the percentage of U.S. No. 1 yield and associated U.S. No. 1 yield was highest for Clearwater at six of nine locations, the exceptions being Colorado, Washington, and the Parma, Idaho site.

Tuber Quality Characteristics and Usage

Processing Characteristics

Clearwater Russet is notable for the production of tubers with low glucose concentrations following long-term storage at temperatures as low as 5.6°C (Fig. 3a). Russet Burbank glucose concentrations exceed the acceptable level of 0.10% at 5.6°C prior to 50 days of storage, whereas Clearwater Russet glucose concentrations remained below 0.10%, and were acceptable for processing even following 250 days of storage, indicative of its resistance to cold-induced sweetening.

The reduced accumulation of reducing sugars in Clearwater Russet tubers is reflected in consistently, acceptable fry color scores (USDA≤2.0) with a low incidence of sugar ends following storage of tubers from 4.4 to 7.2°C (Fig. 3b, Tables 1, 2, 3 and 4). Both Russet Burbank and Ranger Russet produced unacceptably dark fries following storage of tubers at 4.4°C (Tables 1 and 2), with a higher incidence of fry sugar ends as well following storage at 7.2°C (Tables 1 and 2).

Fry color uniformity, reflected as the difference in Photovolt light reflectance readings from the stem to bud end of tubers, is important for processing. Clearwater Russet displayed acceptable light reflectance uniformity (≤9.0) following long-term storage, with the exception of tubers from Oregon (Table 4). Ranger Russet and Russet Burbank consistently exceeded 9.0 photovolt light reflectance units between bud and stem ends at Washington and Idaho, indicative of poorer uniformity of fry color relative to Clearwater Russet at

Table 2 Total yield, U.S. No. 1 yield, percent No. 1's, tuber specific gravity, fry color, and percentage of sugar ends of Clearwater Russet, Ranger Russet, and Russet Burbank in full-season irrigated trials grown in Idaho, Oregon, and Washington, 2003–2007

	ID				
	1	2	OR	WA	**Mean**
Total yield (t/ha)					
Clearwater Russet	52.4 a[a]	55.6 a	110.9 a	69.7 a	**72.2**
Ranger Russet	54.3 a	55.1 a	108.5 a	71.8 a	**72.4**
Russet Burbank	50.0 a	59.7 a	107.7 a	68.0 a	**71.4**
U.S. No. 1 yield (t/ha)					
Clearwater Russet	45.4 a	47.9 a	96.1 a	55.8 b	**61.3**
Ranger Russet	42.9 a	40.8 b	87.7 b	60.9 a	**58.1**
Russet Burbank	28.4 b	35.1 b	59.2 c	45.0 c	**41.9**
% U.S. No. 1					
Clearwater Russet	86 a	86 a	87 a	80 b	**85**
Ranger Russet	78 b	74 b	81 b	85 a	**80**
Russet Burbank	56 c	59 c	55 c	66 c	**59**
Specific gravity[b]					
Clearwater Russet	1.086 a	1.089 a	1.080 a	1.091 a	**1.087**
Ranger Russet	1.086 a	1.090 a	1.077 b	1.084 b	**1.084**
Russet Burbank	1.076 b	1.084 b	1.073 c	1.076 c	**1.077**
Fry color from 4.4 C[c]					
Clearwater Russet	2.3 a	2.0 a	n.a.	1.0 a	**1.8**
Ranger Russet	3.0 b	3.2 b	n.a.	3.2 b	**3.1**
Russet Burbank	3.6 c	3.6 b	n.a.	3.5 b	**3.6**
Fry color from 7.2 C[c]					
Clearwater Russet	0.6 a	1.1 a	0.5 a	0.2 a	**0.6**
Ranger Russet	1.1 b	0.8 a	1.1 b	1.8 b	**1.2**
Russet Burbank	1.2 b	1.0 a	1.6 c	2.0 b	**1.5**
% Sugar ends: 7.2 C					
Clearwater Russet	7 a	0 a	5 a	n.a.	**4**
Ranger Russet	33 b	21 b	9 a	n.a.	**21**
Russet Burbank	31 b	34 b	28 b	n.a.	**31**

Trial locations were Aberdeen (ID-1), Kimberly (ID-2), Hermiston (OR), and Othello (WA). Means represent combined data from the 2003–2004 Tri-State Potato Variety Trials and the 2005–2007 Western Regional Potato Variety Trials; Kimberly data represents the 2005–2007 Western Regional Potato Variety Trials with Kimberly not being represented in Tri-State Trials

[a] Mean values followed by the same letter are not significantly different from one another ($P<0.05$) based on Tukey's test

[b] Specific gravities were determined using the weight-in-air, weight-in-water method

[c] French fry scores rated using USDA standards, with 0=light and 4=dark. A rating ≤2.0 is an acceptable score. Storage at given temperatures prior to frying was 6, 7, and 8 weeks for OR, ID, and WA, respectively. These storage durations follow standard protocols used by industry in allowing 2–3 weeks at 10–13°C for tuber wound healing and a 2–3 degree per week lowering of temperature to the desired holding temperature

these sites (Table 4). Reducing sugar concentrations in tubers of Clearwater Russet were 32–48% lower than Russet Burbank and Ranger Russet, respectively, averaged across all three states (Table 4).

Following a combined 7 months of storage at temperatures of 8.9°C and 6.7°C, sprouts were seen on 100% of tubers from all three varieties (Table 4). Average sprout length following the 7 months of storage was similar between Clearwater Russet and Russet Burbank. Ranger Russet sprout length was consistently the longest reflecting its shorter dormancy among the three varieties.

Over a 5 year period, the post-harvest process rating of Clearwater Russet (rating based upon fry color, reducing sugar concentrations, tuber specific gravity, and sensory evaluations following harvest from the field without storage, and following 60 days of storage at 8.9 and 6.7° C) was superior to the ratings for Ranger Russet and Russet Burbank (Table 5). Of a possible 38 points, Clearwater

Table 3 Total yield, percent U.S. No. 1, specific gravity, and fry color of Clearwater Russet, Ranger Russet and Russet Burbank in full-season trials in the 2005–2007 Western Regional Potato Variety Trials

			ID			OR				
	CA	CO	1	2	3	1	2	3	WA	**Mean**
Total yield (t/ha)										
Clearwater Russet	45.8	50.3	52.9	55.6	69.7	111.9	47.2	65.7	67.9	**63.0**
Ranger Russet	44.6	51.4	54.1	55.2	76.7	107.3	55.1	72.8	73.6	**65.6**
Russet Burbank	40.6	58.9	51.8	59.7	64.8	106.0	55.3	77.0	66.0	**64.5**
U.S. No. 1 yield (t/ha)										
Clearwater Russet	37.7	35.8	46.8	47.9	58.1	96.8	35.6	54.6	53.7	**51.9**
Ranger Russet	35.0	46.2	40.4	40.8	63.5	87.5	33.1	53.1	62.6	**51.4**
Russet Burbank	27.3	47.3	27.7	35.1	42.2	64.5	28.0	35.1	44.5	**39.1**
% U.S. No. 1										
Clearwater Russet	82	71	88	86	83	86	76	83	79	**82**
Ranger Russet	79	90	75	74	83	81	59	73	85	**78**
Russet Burbank	68	81	54	59	65	61	50	45	68	**61**
Specific gravity[a]										
Clearwater Russet	1.085	1.093	1.084	1.089	1.101	1.083	1.083	1.094	1.093	**1.089**
Ranger Russet	1.091	1.095	1.087	1.090	1.100	1.081	1.092	1.093	1.087	**1.091**
Russet Burbank	1.085	1.091	1.075	1.084	1.077	1.076	1.086	1.078	1.080	**1.081**
Fry color[b]										
Clearwater Russet	n.a.	1.0	0.6	1.1	n.a.	0.4	1.0	0.0	0.33	**0.6**
Ranger Russet	n.a.	2.7	1.0	0.8	n.a.	1.1	2.0	0.1	2.0	**1.4**
Russet Burbank	n.a.	1.7	1.0	1.0	n.a.	1.4	2.0	0.8	2.0	**1.4**

Trial locations were Tulelake (CA), San Luis Valley (CO), Aberdeen (ID-1), Kimberly (ID-2), Parma (ID-3), Hermiston (OR-1), Klamath Falls (OR-2), Ontario (OR-3), and Othello (WA); Parma, ID site represents only 1 year of data from 2007—the first year as a site in the trials

[a] Specific gravities were determined using the weight-in-air, weight-in-water method

[b] French fry scores rated using USDA standards, with 0=light and 4=dark. A rating ≤2.0 is an acceptable score. Tubers were evaluated following 6–11 weeks storage at 7.2°C

Russet averaged 76% of this maximum value, whereas Ranger Russet and Russet Burbank were 62% and 47% respectively, indicative of the exceptional processing merit of Clearwater Russet.

Specific Gravity

The mean specific gravities of tubers of Clearwater Russet in full-season trials in Idaho and other western sites were comparable to values for Ranger Russet and 0.008–0.010 greater than mean specific gravities observed for Russet Burbank (Tables 1, 2 and 3).

Tuber Defects

Using a five point rating scale with a value of 5.0 indicative of no defects, Clearwater Russet was rated 4.9 for both growth cracks and second growth (Table 6) during 5 years of evaluations in both the Tri-State and Western Regional Potato Variety Trials. The low incidence of external defects has contributed to its high U.S. No. 1 yield relative to Russet Burbank and Ranger Russet. Clearwater Russet is intermediate between Ranger Russet and Russet Burbank for incidence of hollow heart/brown center and is similar to them in susceptibility to shatter bruise (Table 6). Percentage of internal brown spot (heat necrosis) was higher for Clearwater Russet than for Ranger Russet and Russet Burbank (Table 6). The higher incidence was directly attributable to data from the Hermiston, Oregon site, located in the southern Columbia Basin. In 5 years of trials at Hermiston, the average percentage of internal brown spot for Clearwater Russet was 42%, while other trial sites, including the northern Columbia Basin trial site at Othello, Washington, reported little or no internal brown spot. The factor(s) contributing to the greater expression of internal brown spot at Hermiston have not been identified and it is recommended that producers in the southern Columbia Basin either not grow Clearwater Russet or initially conduct small scale trials of Clearwater Russet to assess whether internal brown spot will be problematic for them. Net necrosis/vascular discoloration of Clearwater Russet was identical to the value for Russet Burbank and was 45% of

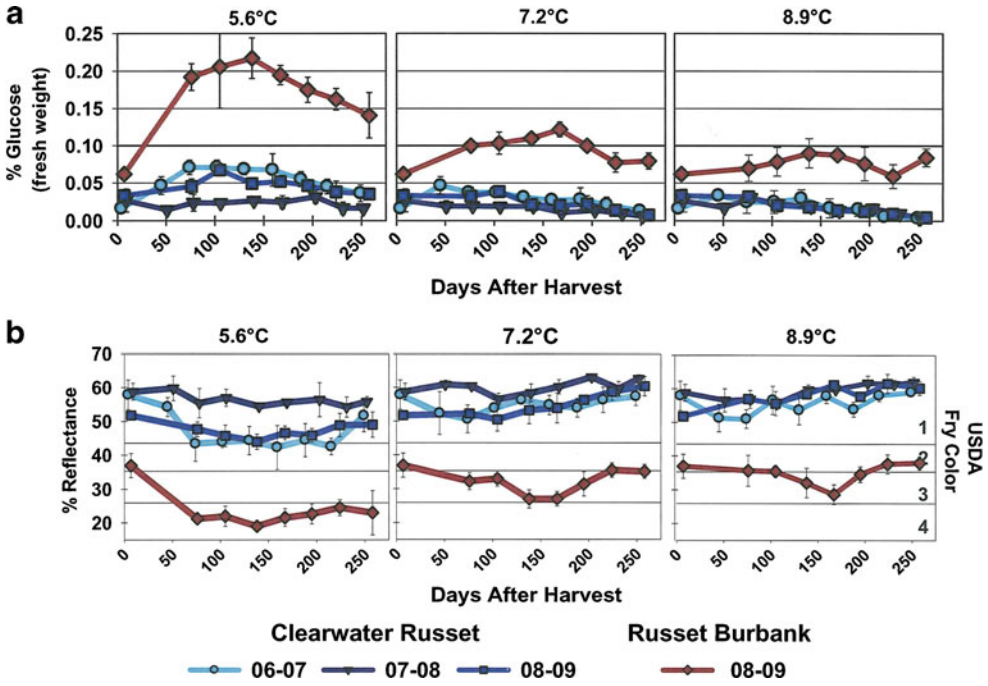

Fig. 3 **a**. Tuber glucose concentrations and **b.** fry colors of Clearwater Russet over a 3-year period relative to Russet Burbank, following 0–250 days of storage at 5.6, 7.2, and 8.9°C. These three storage temperatures reflect an initial storage of harvested tubers for 14 days at 12.8°C followed by an incremental lowering of the temperature by 0.28°C per day until the three storage temperatures were reached. Glucose concentrations and fry colors of Russet Burbank represent data from 1 year, and are representative of a typical pattern for that cultivar. Fry colors with Photovolt light reflectance readings of ≥35 and USDA ratings of ≤2.0 are considered acceptable

the value reported for Ranger Russet (Table 6); tubers in field trials were not individually ELISA tested for presence of PLRV, making it difficult to effectively distinguish between net necrosis and vascular discoloration symptoms, thus the combining of the two symptoms into one category. Blackspot bruise ratings from tubers harvested in field trials were least severe for Clearwater Russet, with a rating of 4.5; a considerably more resistant rating than the 3.3 reported for Ranger Russet, a cultivar known for its susceptibility to blackspot bruising (Table 6). Tuber shrinkage of Clearwater Russet averaged across storage temperatures of 5.6°C, 7.2°C, and 8.9°C over a 3 year period of evaluation was 1.3% greater than that of Russet Burbank (Table 6).

Sensory Evaluations

Taste panel evaluations of baked potatoes support fresh use of Clearwater Russet following 5–6 months of storage at 4.4°C, with sensory ratings comparable or identical to Russet Burbank (Table 7). In early-storage evaluations, Clearwater Russet was rated slightly lower than Russet Burbank for texture, flavor, and overall appeal.

Disease and Pest Responses

Evaluations of disease responses for Clearwater Russet were based on data collected from replicated field trials conducted for a minimum of 2 years. Verticillium wilt (*Verticillium dahlia)* evaluations were conducted at Aberdeen, Idaho and Hermiston, Oregon using naturally occurring inocula and protocols described by Corsini et al. (1988). Common scab (*Streptomyces scabies*) was evaluated on tubers collected from three replicates from field trials arranged in a randomized complete block (RCB) using naturally occurring inocula at Aberdeen, Idaho. In 2007, Clearwater Russet also was evaluated for common scab response at Becker, Minnesota and Presque Isle, Maine as described by Haynes et al. (2010, On-Line First). Common scab evaluations also were conducted by Dr. Walt Stevenson and Vaughan James, University of Wisconsin-Madison in 2007–2008 at Antigo, Wisconsin in fields with a history of common scab; trial reports for the 2007 and 2008 trials respectively as of January 2010 can be found at: http://www.plantpath.wisc.edu/wivegdis/2007%20final%20reports/wrs513%20antigo%20scab%20var%20rept%20final.pdf and at http://www.plantpath.wisc.edu/wivegdis/2008/2008-5%20antigo%20scab%20var%20rept%20prelim.pdf

Early blight *(Alternaria solani)* evaluations were conducted at Aberdeen and were based on visual estimates of the amount of leaf area infected in three replicate plots of a RCB design.

Late blight *(Phytophthora infestans*) field evaluations were conducted at Corvallis, Oregon as described by Mosley et al. (2003). Evaluations of PLRV, PVY, and PVX resistances were conducted at Kimberly, Idaho using virus-infected spreader rows as described by Corsini et al. (1994). Primary foliar and tuber symptoms caused by PVY strains were conducted in a greenhouse at Aberdeen

Table 4 Post-harvest ratings of Clearwater Russet, Ranger Russet, and Russet Burbank following 7 months of storage (3 months at 8.9°C and 4 months at 6.7°C)

	Photovolt Reading[a]			Difference[b]: Stem -vs- Bud		% Reducing sugars[d]			Tuber Sprouting[e]
Location/Variety	Stem	Bud	Avg.		USDA Color rating[c]	Stem	Bud	Avg.	Sprout Length (mm)
Washington									
Clearwater Russet	45.3	52.2	48.7	8.0	0	0.60	0.45	0.53	33
Ranger Russet	26.2	35.2	30.7	9.7	1.5	1.73	0.88	1.30	54
Russet Burbank	30.4	41.2	35.8	11.2	0.8	1.20	0.58	0.89	33
Idaho									
Clearwater Russet	43.8	47.2	45.5	6.5	0	0.65	0.53	0.59	36
Ranger Russet	31.0	40.9	36.0	10.4	0.3	1.38	0.65	1.01	62
Russet Burbank	31.3	41.4	36.3	11.5	0.5	1.30	0.60	0.95	25
Oregon									
Clearwater Russet	30.2	46.4	38.3	16.6	1.0	1.98	0.53	1.25	37
Ranger Russet	20.3	34.1	27.2	14.0	2.3	3.43	1.03	2.23	56
Russet Burbank	21.3	38.6	29.9	17.3	2.0	2.43	0.85	1.64	32

All post-harvest evaluations and ratings were conducted at Pullman, WA in 2003–2007 using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA

[a] Fries (0.95×2.87 cm) were fried at 191°C for 3.5 min and color was measured with a Photovolt reflectance meter (model 577, Photovolt Instruments Inc., Minneapolis, MN) within 3 min of removal from oil. A Photovolt light reflectance reading of ≤19 is considered unacceptably dark (see note 3 below)

[b] A difference ≥9 Photovolt light reflectance units between bud and stem end constitutes non-uniform fry color. Values represent an average of actual Photovolt differences in each of 4 years and therefore do not relate directly to averaged stem and bud values listed in the table

[c] USDA color (0=light and 4=dark) ratings were assigned based upon Photovolt light reflectance readings of the darkest ends of fries (typically stem ends); Photovolt readings ≥31=USDA 0, 25–30=USDA 1, 20–24=USDA 2, 15–19=USDA 3, ≤14=USDA 4. Data are averaged over years

[d] Glucose+Fructose (dry matter basis) were assayed by the dinitrophenol method of Ross (1959). Acceptable values for processing are ≤2.6%

[e] Tubers of all varieties at all locations were 100% sprouted following the 7 month storage regime

by manually inoculating plants grown from virus-tested, certified minitubers. Plants were inoculated with one isolate each of the $PVY^{N\text{-}Wi}$ (syn. $PVY^{N:O}$), PVY^{NTN}, and PVY^{O} strains. The plants were then tested using ELISA 3 weeks post-inoculation and evaluated weekly thereafter until maturity. Tuber symptoms were evaluated at harvest and then again after 30 days at room temperature. Corky ringspot (tobacco rattle virus) evaluations were conducted in a heavily infested field in the Egin Bench region of Idaho in plots arranged in a RCB design with three replications, as well as in the Columbia Basin of Washington and Oregon using protocols described by Brown et al. (2000). Storage disease evaluations were performed as described by Corsini and Pavek (1986). Columbia root-knot nematode *(Meloidogyne chitwoodi)* evaluations were conducted in the Columbia Basin using methods described in Brown et al. (2006).

Clearwater Russet is notable for having resistance to tuber late blight and potato virus X and moderate levels of resistance to Verticillium wilt, common scab, and potato virus Y^{O} in field evaluations where the virus was both mechanically inoculated and aphid transmitted (Tables 8 and 9).

Mechanical inoculations of Clearwater Russet in the greenhouse with common and necrotic strains of PVY indicate that the foliar response of Clearwater Russet to PVY infection, assessed using a foliar visual index, is similar to Ranger Russet and Russet Burbank for $PVY^{N\text{-}Wi}$, reduced for PVY^{NTN}, and similar to Russet Burbank but reduced relative to Ranger Russet for PVY^{O} (Table 9). Foliar infection by all three PVY strains was visually apparent in Clearwater Russet with no asymptomatic expression observed for any of the three strains. Analogous to Russet Burbank, no tuber necrosis was observed in Clearwater Russet following infection by the three PVY strains, whereas Ranger Russet exhibited tuber necrotic symptoms following infection with $PVY^{N\text{-}Wi}$ and PVY^{NTN}.

Clearwater Russet is susceptible to bacterial ring rot (*Clavibacter michiganensis* subsp. *sepedonicus*) and exhibits strong foliar symptoms which include early dwarfing, rosette plant growth, leaf interveinal chlorosis and necrosis, leaf marginal necrosis, and green wilt. Average number of days from planting to first symptoms of infection was 78 (+/−20) in 2 years of evaluations in a RCB design consisting of 3 replicates of seven inoculated seed pieces

Table 5 Mean post-harvest ratings[a] of Clearwater Russet, Ranger Russet, and Russet Burbank in full-season trials in the 2003–2007 Tri-State and Western Regional Potato Variety Trials

	Washington	Idaho	Oregon	**Mean**
Clearwater Russet	30.7	32.2	24.2	**29.0**
Ranger Russet	24.6	28.8	17.7	**23.7**
Russet Burbank	21.9	19.5	12.1	**17.9**

Post-harvest evaluations and ratings were conducted at Pullman, WA using tubers produced in trials at Aberdeen, ID, Hermiston, OR, and Othello, WA.

[a] Values were assigned based on the sum of individual ratings for fry color from the field, after storage at 8.9 and 6.7°C (56 days) (0–5 scale, 1=dark, 5=light), reducing sugar concentrations following 56 days storage at 8.9 and 6.7°C (1–5 scale, 1=high, 5=low), specific gravity (0–5 scale, 1=low, 5=high), and average sensory evaluations by taste panels (1–5 scale, 5=best). An additional 3 points could be added for high fry color uniformity, resulting in a maximum possible value of 38. Higher values are indicative of superior post-harvest attributes

with non-inoculated controls planted adjacent for symptom comparison (Rob Davidson, Colorado State University, Extension Seed Potato Specialist, unpublished data). Foliar expression of infection is therefore obvious within the critical period of seed certification (within 100 days after planting), meaning detection of the presence of bacterial ring rot infection prior to final field inspection is likely. Symptoms of bacterial ring rot infection in the tuber were not found during the 2 years of study indicating a low probability of tuber symptoms with infection.

Biochemical and Nutritional Characteristics

Tubers of Clearwater Russet, Ranger Russet, and Russet Burbank, grown at Aberdeen, ID, were analyzed 6 weeks after harvest over a 3-year period to assess biochemical and nutritional components (Table 10). Clearwater Russet was comparable in dry matter and sucrose concentrations to Ranger Russet and was higher than Russet Burbank for these tuber constituents.

Glucose percentages were 33% and 45% lower than levels observed in Ranger Russet and Russet Burbank, respectively. The lower glucose concentrations observed in tubers of Clearwater Russet correlate well with observations of a 92% reduction in basal acid invertase activity relative to Russet Burbank (Gupta, unpublished data). Acid invertase has been identified as a critical enzyme in the conversion of sucrose to reducing sugars such as glucose, with lower acid invertase activity being associated with cold-induced sweetening resistance.

Protein concentrations in tubers of Clearwater Russet are significantly greater than those of Ranger Russet and Russet Burbank (Table 10). Over a 3 year period, Clearwater Russet averaged 12% and 33% more protein than Ranger Russet and Russet Burbank, respectively, indicating an enhanced level of dietary protein relative to industry standards. Vitamin C content of Clearwater Russet was similar to that of Russet Burbank, both of which were lower than Ranger Russet, a cultivar noted for its high levels of ascorbic acid (Love et al. 2004). Total glycoalkaloids for

Table 6 Evaluation of internal and external defects of Clearwater Russet, Ranger Russet, and Russet Burbank in Tri-State and Western Regional Trials (2003–2007)

Cultivar	Growth cracks[a,c]	Second growth[a,d]	Shatter bruise[a,e]	Hollow heart/BC[b,f]	% Internal brown Spot[g]	Net necrosis/ Vasc. discol.[h]	Blackspot bruise[a,i]	Tuber shrinkage[j]
Clearwater Russet	4.9	4.9	4.2	3.2	11.1	1.4	4.5	6.5
Ranger Russet	4.4	4.6	4.5	0.3	1.2	3.1	3.3	n.a.
Russet Burbank	3.6	3.5	4.3	6.9	5.9	1.4	4.0	5.2

[a] Rated using a 1–5 scale with 1=severe and 5=none observed

[b] Rated as the percentage of tubers >341 g with hollow heart and brown center

[c] Average of 26 sites

[d] Average of 19 sites

[e] Average of 12 sites

[f] Average of 30 sites

[g] Average of 23 sites

[h] Average of 21 sites; expressed as percentage of tubers displaying symptoms

[i] Average of 14 sites

[j] Value is percent weight loss following 9 months of storage in 2007–2009 (3 years of storage data). Value reflects an average across three storage temperatures of 5.6, 7.2, and 8.9°C conducted at Kimberly, ID

Table 7 Sensory evaluations of Clearwater Russet and Russet Burbank baked potatoes

Cultivar	Early-storage[a]				Late-storage[b]			
	Color	Texture	Flavor	Overall appeal	Color	Texture	Flavor	Overall appeal
Clearwater Russet	6.2	5.5	5.4	5.5	6.1	5.5	5.5	5.5
Russet Burbank	6.5	6.1	5.9	6.0	6.1	5.6	5.3	5.5

Blind sensory evaluations were conducted in Blackfoot, ID using 10–12 trained panelists. Values are the means of two sessions conducted over a 2 year period from 2006 to 2007 (1 session/year). Tubers were baked in an oven at 190°C for 1 h and rated for color, texture, flavor, and overall appeal using a scale with 1=very poor quality and 9=exceptional quality

[a] Early-storage evaluations were conducted approximately 1 month after harvest, prior to the time that the final holding temperature of 4.4°C was reached

[b] Late-storage evaluations were conducted following 5–6 months storage at 4.4°C

Clearwater Russet were 1.6 mg/100 g tuber fresh weight, which were half the levels of the check varieties and far below the critical threshold of 20 mg/100 g tuber fresh weight.

Management

A limited number of studies for developing management practices optimal for the production of Clearwater Russet were conducted in southern Idaho and in the northern Columbia Basin of Washington. Results of these studies may provide growers in these and other production regions with a basis for developing appropriate management guidelines for their locale.

Southern Idaho

Optimal seed size for Clearwater Russet is about 55–85 g. Seed should be planted in soil of optimal temperature (7.2–12.8°C) to minimize the potential for soft rot decay. Dry rot potential of seed lots should also be determined and seed should be treated with an effective fungicide when needed. Planting depth should be 15–20 cm from the top of the seed piece to the top of the hill. Seed piece spacing for 91 cm wide rows should be 25–30 cm for fresh market use, but spacing may be increased to 33 cm for processing if a larger size profile is desired.

Clearwater Russet has exhibited good resistance to metribuzin when applied at labeled rates. It has an erect, medium sized vine with medium-late maturity but competes reasonably well with weeds after row closure during early to mid-tuber bulking.

Soils infested with root-knot nematodes or a history of severe early die problems should be fumigated. Routine fungicide applications should also be made to prevent serious early blight infections. Early blight control for tubers in fields scheduled for storage can be facilitated by minimizing tuber skinning and bruising during harvest and subsequent handling and by avoiding harvesting in wet weather conditions.

Table 8 Disease response of Clearwater Russet relative to Ranger Russet, and Russet Burbank

Cultivar	Vert. wilt	Root knot nematode	Common scab	Early blight		Late blight		Symptoms of virus infection		Storage diseases	
				Foliar	Tuber	Foliar	Tuber	Net necrosis[a]	Corky ringspot	Soft rot	Dry rot
Clearwater R.	MR	S	MR	S	MS	S	R	S	S	S	S/MS[b]
Ranger R.	MR	S	S	S	MS	S	VS	MS	S	MS	MS
R. Burbank	S	S	MR	S	MS	S	S	S	S	S	S

Responses of Clearwater Russet to diseases were based on a minimum of 2 years of controlled field evaluations. Responses were defined as very resistant (VR), resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S), and very susceptible (VS). Disease evaluations were conducted at the following locations: *Verticillium wilt* - Aberdeen, ID and Hermiston, OR; *Root Knot Nematode, Corky ringspot* – Prosser, WA; *Common scab* - Aberdeen, ID, Presque Isle, ME, Becker, MN, and Antigo, WI; *Early blight, Pectobacterium (Erwinia) soft rot, Fusarium dry rot* - Aberdeen, ID; *Virus net necrosis* - Kimberly, ID; *Late blight* – Corvallis, OR

[a] Net necrosis symptoms are based on seed borne infections following aphid vectored field infection with PLRV from infected source plants inter-planted among plots

[b] S on *Fusarium sambucinum;* MS on *Fusarium solani* var. *coeruleum*

Table 9 Virus susceptibility and foliar symptoms and tuber symptoms of Clearwater Russet, Ranger Russet, and Russet Burbank. Foliar and tuber symptoms are from primary infections evaluated in a greenhouse

Cultivar	Virus susceptibility[a]			Foliar PVY strain index[b] and symptoms[c]			PVY tuber symptoms present		
	PLRV	PVX	PVY^O	N-Wi	NTN	O	N-Wi	NTN	O
Clearwater R.	VS	R	MR	1.2 (MO, NS)	0.8 (MO)	1.3 (VN, NS, LF_{drop})	no	no	no
Ranger R.	S	R	MR	1.3 (YF)	1.7 (YF, VN)	3.0 (VN, LF_{drop})	yes	yes	no
R. Burbank	VS	VS	S	1.2 (MO)	1.5 (MO)	1.7 (MO)	no	no	no

[a] Very resistant (VR), resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S), and very susceptible (VS). Virus susceptibility (Kimberly, ID) ratings from ELISA tests of plants grown-out from plants infected in the field the previous season

[b] Foliar visual index=average of visual index readings from all PVY isolates. Index is based on a foliar symptom scale and is calculated by dividing the sum of each weekly reading by the number of readings (four replications of each clone per isolate). Foliar mosaic scale 0=no symptoms; 1=mild; 2=typical; 3=severe

[c] Typical foliar symptoms; mosaic (MO), necrotic spots (NS), yellow flecking (YF) in leaflets, veinal necrosis (VN) on underside of leaflets, lower leaf necrosis and drop (LF_{drop})

Nutrient Management Total seasonal nitrogen requirements for Clearwater Russet are approximately 25% less than Russet Burbank for a set amount of yield to be produced. Typically, 1/3 to 1/2 of the seasonal N requirement should be applied by row closure, with subsequent in-season applications being based on petiole nitrate concentrations. For southern Idaho, total soil plus fertilizer N recommendations range from about 200 kg N/ha in areas with a 45 t/ha yield potential to 270 kg N/ha in areas with a 67 t/ha yield potential. Nitrogen uptake decreases significantly after mid August so N applications should not be made after that time.

Nitrogen response studies conducted for 2 years at Aberdeen, Idaho indicate that optimal petiole nitrate concentrations for Clearwater Russet should be about 18,000–22,000 ppm at the end of tuber initiation, and about 15,000–18,000 ppm during mid-bulking. During late bulking, petiole nitrate concentrations should be allowed to decrease to 7,000–10,000 ppm.

Phosphorus, potassium and micronutrient requirements have not been established for Clearwater Russet. Therefore, it is recommended that growers follow local nutrient management recommendations for Russet Burbank until new guidelines for Clearwater Russet become available.

Irrigation Management Seasonal irrigation requirements for Clearwater Russet are similar to those for Russet Burbank, although Clearwater Russet is significantly more

Table 10 Biochemical analyses of Clearwater Russet, Ranger Russet, and Russet Burbank tubers from the 2005–2007 Western Regional Potato Variety Trials at Aberdeen, ID

Cultivar	Dry matter (%)	Sucrose[b] (% FWB[a])	Glucose[b] (% FWB[a])	Protein[c] (% DWB[a])	Vitamin C[d] (mg/100g FWB[a])	Total Glycoalkaloids[e] (mg/100g FWB[a])
Clearwater Russet	22.0	0.18	0.06	6.4 a[f]	24.9	1.6
Ranger Russet	22.1	0.19	0.09	5.7 b	34.3	3.4
Russet Burbank	19.3	0.16	0.11	4.8 c	23.2	3.5

Analyses were conducted on freeze-dried tuber tissue at Aberdeen, ID; tissue was taken from tubers stored at 7.2°C for 6 weeks following their harvest

[a] *FWB* Fresh Weight Basis; *DWB* Dry Weight Basis; Sucrose and glucose values of 0.15% and 0.10% respectively are maximum values for acceptable fry color in this evaluation, with glucose being the greater contributor to fry color

[b] Sugar concentrations were calculated according to: Glucose and sucrose measurements in potatoes, Application Note No. 102, Scientific Division, Yellow Springs Instrument Co., Yellow Springs, Ohio 45387

[c] Protein content was determined using a Coomassie blue protein assay developed from the protocol of Bradford (1976)

[d] Vitamin C (ascorbic acid) content in tubers was determined using a microfluorometric method detailed in the Official Methods of Analysis Handbook, 14th edition, sections 43.069–43.075

[e] Total glycoalkaloids was determined using the protocol of Bergers (1980)

[f] Mean values followed by the same letter are not significantly (n.s.) different from one another ($P<0.05$) based on Student's *t* test

resistant to water stress-related tuber defects. Therefore, available soil moisture (ASM) should be maintained within the range of 70–85% for optimal yield and quality. Plant water uptake decreases appreciably in late August, so irrigation application rates need to be adjusted according to soil moisture measurements to avoid developing excessively wet soil conditions that promote disease and enlarged lenticels. However, soil moisture should be maintained above 60% ASM conditions during tuber maturation and harvest to minimize tuber dehydration and blackspot bruise.

Harvest Management Irrigation rates should be gradually reduced during the remaining few weeks prior to vine kill to avoid excessive soil moisture and allow tuber hydration to decrease to a moderate level during skin set. Standard practices for minimizing tuber impact damage during harvest and transfer to storage should be followed to reduce the potential for shatter and blackspot bruise.

Storage Management Over a 3 year period, tubers of Clearwater Russet and Russet Burbank were evaluated for response to *Fusarium* dry rot. Tubers were bruised and inoculated with a 50/50 mix of Thiabendazole resistant: susceptible strains of *F. sambucinum* and then were cured at 12.8°C and 95% relative humidity for 2 weeks. They were stored at 7.2°C for approximately 3 months and tubers were evaluated for the percentage of tuber tissue displaying dry rot decay and the incidence of the disease, expressed as the percentage of tubers having >5% decayed tissue. The mean percentage of tissue decay for Clearwater Russet was 31% while that of Russet Burbank was 12%. The percent incidence of potatoes with at least 5% decay was also significantly higher in Clearwater Russet (63%) than in Russet Burbank (39%). Dry rot tests done with one *F. sambucinum* isolate at Aberdeen, Idaho showed that Clearwater Russet (4.3) and Russet Burbank (4.7) had similar susceptible ratings (1–5 scale with 5 most severe) over 3 years. Together these results would indicate that Clearwater Russet has equal to or higher susceptibility to *F. sambucinum* than Russet Burbank. Clearwater Russet is only moderately susceptible to dry rot caused by *F. solani* var. *coeruleum*. On the basis of these results, additional care during harvest and handling is recommended for Clearwater to mitigate wounding that allows for entry and infection of tubers by *Fusarium*.

Tuber dormancy length of Clearwater Russet is approximately 58 days shorter than Russet Burbank when held at storage temperatures ranging from 5.6 to 8.9°C. Treatment for sprout inhibition with chlorpropham should be made within the first 2 months of storage if storing at relatively warmer temperatures of 7.2–8.9°C. Shrinkage or percent weight loss throughout the storage season is similar to that of Russet Burbank. Storage temperature recommendations for fresh market use of Clearwater Russet are from 5.6 to 7.2°C. Clearwater Russet can be successfully stored for fresh market up to 9 months in the absence of problematic disease development within the storage.

Clearwater Russet has excellent processing qualities as previously outlined in the section on processing characteristics. Percent glucose (fresh wt basis) is below 0.08% at 5.6°C and below 0.05% at 7.2 and 8.9°C throughout 9 months storage at these temperatures. At harvest, percent sucrose concentrations for Clearwater Russet were higher than Russet Burbank in 2 of 3 years of evaluation at Kimberly, ID. However, during storage evaluations over a 9 month period, sucrose concentrations were very similar between the two varieties. Fry color is lightest (USDA 1 or lighter) at 7.2 and 8.9°C storage temperatures with the 8.9°C temperature ameliorating seasonal variability in sugar content and fry color. Mottling, a dark, uneven coloration which can occur in fried products, is occasionally observed in tubers held at 5.6°C, but is seldom observed at 7.2 and 8.9°C storage temperatures. For the frozen processing market, it is recommended to store Clearwater Russet at 7.2–8.9°C for optimum processing quality unless a known stress occurred during the growing season that may warrant consideration of slighter higher temperatures.

Columbia Basin of Washington

Clearwater Russet grown in the Columbia Basin typically produces tubers smaller in size than Ranger Russet and Russet Burbank. To ensure adequate tuber size and processing yield, Clearwater Russet should be planted relatively early using 42.5–80.0 g seed pieces spaced between 25.4 and 30.5 cm and allowed to grow >150 days. Final planting depth should be 20 cm below soil level in 86.4 cm spaced rows.

Water management is very similar to guidelines for Russet Burbank. Available soil moisture should be maintained at 75–85% from full emergence until late bulking; as vines senesce, ASM should be reduced to 60–65%.

Until additional fertility management trials can be conducted for Clearwater Russet, growers should follow the nutrient management guidelines established for Russet Burbank (Lang et al. 1999). Specific nitrogen recommendations for Clearwater Russet include 140.1–168.1 kg ha^{-1} of available nitrogen (soil residual+applied) in the root zone at emergence. Petiole samples should be collected prior to row closure and continued through the season until late bulking; petiole NO_3 concentrations of 20,000–26,000 ppm and total soil nitrogen above 56.0 kg ha^{-1} should be maintained until the start of early bulking (approximately 90 DAP). Thereafter, allow depletion of

soil nitrogen with a corresponding decline in petiole reading between 15,000 and 19,000 ppm at mid-bulking (approximately 115 DAP), and then between 8,000 and 12,000 ppm at late bulking (approximately 125 DAP). Total season nitrogen (including soil residual) for Clearwater Russet should be between 370 and 400 kg ha^{-1} in a typical growing season with approximately two-thirds applied through the irrigation water between 60 and 115 DAP. Specific recommendations for organic production have not been established.

Seed Availability

In 2009, seed was available from potato seed growers in Idaho, Michigan, and North Dakota. Contact information for these growers is listed at the Potato Variety Management Institute (PVMI) website. Smaller amounts of seed, for research purposes, can be obtained by contacting the corresponding author. The University of Idaho, acting on behalf of the Northwest (Tri-State) Potato Variety Development Program, has filed an application for Plant Variety Protection for Clearwater Russet, with licensing of this cultivar by the Potato Variety Management Institute (PVMI).

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References

Bergers, W.W. 1980. A rapid quantitative assay for solanidine glycoalkaloids in potatoes and industrial potato protein. *Potato Research* 23: 105–110.

Bradford, N.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein using the principle of protein dye binding. *Analytical Biochemistry* 72: 248–254.

Brown, C.R., H. Mojtahedi, G.S. Santo, P. Hamm, J.J. Pavek, D. Corsini, S. Love, J.M. Crosslin, and P.E. Thomas. 2000. Potato germplasm resistant to corky ringspot disease. *American Journal of Potato Research* 77: 23–27.

Brown, C.R., H. Mojtahedi, S. James, R.G. Novy, and S. Love. 2006. Development and evaluation of potato breeding lines with introgressed resistance to Columbia root-knot nematode (*Meloidogyne chitwoodi*). *American Journal of Potato Research* 83: 1–8.

Corsini, D., and J.J. Pavek. 1986. Fusarium dry-rot resistant potato germplasm. *American Potato Journal* 63: 629–638.

Corsini, D.L., J.J. Pavek, and J.R. Davis. 1988. Verticillium wilt resistance in non-cultivated tuber-bearing *Solanum* species. *Plant Disease* 75: 148–151.

Corsini, D.L., J.J. Pavek, M.W. Martin, and C.R. Brown. 1994. Potato germplasm with combined resistance to leafroll virus and viruses X and Y. *American Potato Journal* 71: 377–385.

Haynes, K.G., L.A. Wanner, C.A. Thill, J.M. Bradeen, J. Miller, R.G. Novy, J.L. Whitworth, D.L. Corsini, and B.T. Vinyard. 2010. Common Scab Trials of Potato Varieties and Advanced Selections at Three U.S. Locations. *American Journal of Potato Research* Online First electronic version: doi10.1007/s12230-010-9132.

Hoyman, W.G., and R.C. Holland. 1974. Nooksack: A russet potato adapted to northwestern Washington. *American Potato Journal* 51: 99–103.

Johansen, R.H. 1965. Norgold Russet, a new, early maturing potato variety with good type and scab resistance. *American Potato Journal* 42: 201–204.

Johansen, R.H., E.P. Lana, and A.P. Benson. 1963. Viking, a new, high-yielding red-skinned potato variety. *American Potato Journal* 41: 253–255.

Lang N.S., R.G. Stevens, R.E. Thornton, W.L. Pan and S. Victory. 1999. Nutrient management guide: Central Washington irrigated potatoes. Washington State University Experiment Station Extension Bulletin EB1882.

Love, S.L., T. Salaiz, B. Shafii, W.J. Price, A.R. Mosley, and R.E. Thornton. 2004. Stability of expression and concentration of ascorbic acid in North American potato germplasm. *HortScience* 39(1): 156–160.

Mosley A, S. Yilma, D. Hane, S. James, K. Rykbost, C. Shock, B. Charlton, E. Eldredge, and L. Leroux. 2003. Oregon. In: K.G. Haynes (ed), *National Potato Germplasm Evaluation and Enhancement Report*, 2001. pp. 369–388.

Novy, R.G., D.L. Corsini, S.L. Love, J.J. Pavek, A.R. Mosley, S.R. James, D.C. Hane, C.C. Shock, K.A. Rykbost, C.R. Brown, and R.E. Thornton. 2002. Bannock Russet: A dual purpose, russet potato cultivar with high U.S. No. 1 yield and multiple disease resistances. *American Journal of Potato Research* 79: 147–153.

Pavek, J.J., D.R. Douglas, H.C. McKay, and R.E. Ohms. 1973. Targhee: An oblong russet potato variety with attractive tubers and high resistance to common scab. *American Potato Journal* 50: 293–296.

Pavek, J.J., D.L. Corsini, D.R. Douglas, R.E. Ohms, J.G. Garner, H.C. McKay, C. Stanger, G.E. Vogt, W.C. Sparks, R. Kunkel, J.R. Davis, A.J. Walz, C.E. Dallimore, and J. Augustin. 1978. Butte: A long russet potato variety with excellent dehydrating quality. *American Potato Journal* 55: 685–690.

Pavek, J.J., D.L. Corsini, S.L. Love, D.C. Hane, D.G. Holm, W.M. Iritani, S.R. James, M.W. Martin, A.R. Mosley, J.C. Ojala, C.E. Stanger, and R.E. Thornton. 1992. Ranger Russet: A long russet potato variety for processing and fresh market with improved quality, disease resistance, and yield. *American Potato Journal* 69: 483–488.

Ross, F.A. 1959. Dinitrophenol method for reducing sugars. In *Potato processing*, ed. W.F. Talburt and O. Smith, 469–470. Westport: AVI.

United States Standards for Grades of Potatoes. 1997. United States Department of Agriculture, Agricultural Marketing Service. p 2.