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Rainier Russet: A Dual Use Russet Potato with Long Tuber Dormancy, Excellent Process Quality, and High Early Harvest Packaging Efficiency

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Abstract

‘Rainier Russet’ was released in 2020 as a medium- to late-maturing selection with russeted tubers. Total yields are less, but similar to controls ‘Ranger Russet’ and ‘Russet Burbank’, and U.S. No. 1 yields are higher than Russet Burbank with increased tubers > 284 g. Compared to controls, it has high protein levels, high specific gravity, excellent fry color and flavor ratings, low acrylamide potential, good post-harvest merit scores for processing quality, and few internal and external tuber defects. Rainier Russet is susceptible to blight diseases, PVY, and Fusarium dry rot (*F. solani* var. *sambucinum*), but resistant to common scab (*Streptomyces scabies*) and Fusarium dry rot (*F. solani* var. *coeruleum*). Compared to Russet Burbank, tubers are less susceptible to hollow heart/brown center, secondary growth, growth cracks, and internal brown spot but higher tuber defects for net necrosis and shatter bruise with similar blackspot bruise potential. Rainier Russet is noted for its long tuber dormancy compared to Russet Burbank.

Resumen

'Rainier Russet' se liberó en 2020 como una selección de maduración media a tardía con tubérculos escamosos. Los rendimientos totales son menores, pero similares a los testigos 'Ranger Russet' y 'Russet Burbank', y los rendimientos del No. 1 de EE. UU. son más altos que los de Russet Burbank con un aumento de tubérculos >284 g. En comparación con los testigos, tiene altos niveles de proteína, alta gravedad específica, excelentes calificaciones de color y sabor, bajo potencial de acrilamida, buenos puntajes de mérito poscosecha para la calidad del procesamiento y pocos defectos internos y externos del tubérculo. Rainier Russet es susceptible a las enfermedades del tizón, PVY y a la podredumbre seca por Fusarium (F. solani var. sambucinum), pero resistente a la sarna común (Streptomyces scabies) y a la podredumbre seca por Fusarium (F.

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solani var. coeruleum). En comparación con Russet Burbank, los tubérculos son menos susceptibles al corazón hueco/centro marrón, al crecimiento secundario, a las grietas de crecimiento y a la mancha marrón interna, pero tienen mayores defectos en los tubérculos para la necrosis neta y el hematoma de rotura con un potencial similar de hematomas de manchas negras. Rainier Russet se destaca por su larga latencia de tubérculo en comparación con Russet Burbank.

Keywords *Solanum tuberosum* · Variety · Breeding · Processing Potatoes · Fresh Potatoes

Introduction

Cv. Rainier Russet (AO06191-1) was developed by the Northwest Potato Variety Development Program (NWPVDP; also known as the Tri-State Breeding Program). It originated from a hybridization conducted in 2006 by personnel of the USDA-Agricultural Research Service (ARS) at Aberdeen, ID between parents A99134-1 and cv. Canela Russet (breeding clone AC92009-4RU at the time of hybridization) (Fig. 1). Parents were selected for their visual tuber appearance, market use potential, and disease resistance. Canela Russet (AC92009-4RU) was subsequently released by Colorado State University and the USDA-ARS as a medium-maturing variety for the fresh market with long dormancy, an oblong-long tuber shape, high specific gravity, and resistance to hollow heart, blackspot bruising, secondary growth, early blight, and powdery scab (Holm et al. 2012). Canela Russet blackspot bruising resistance was a component of the decision-making in the hybridization that generated Rainier Russet, with female parent A99134-1 being susceptible to blackspot bruising.

Rainier Russet is characterized by its oblong to long tuber shape, heavily russeted tuber skin, suitable specific gravity, similar yields to cvs. Russet Burbank and Ranger Russet, and higher yields than cv. Russet Norkotah, high protein content, light fry color, low acrylamide levels, excellent taste, long tuber dormancy, and few internal and external tuber defects. Additionally, Rainier Russet is resistant to Fusarium dry rot (*Fusarium solani* var. *coeruleum*) and common scab (*Streptomyces scabies*) and has moderate levels of resistance to early blight (foliar; *Alternaria solani*).

Rainier Russet was originally designated as AO06191-1 after initial selection for its desirable tuber phenotype in the field from single hills planted in 2009 at Powell Butte, OR. Rainier Russet was further evaluated at Hermiston, OR as four hill plots in 2010 and 17-hill plots in Hermiston and Ontario, OR in 2011. It was then evaluated in replicated state-wide trails throughout Oregon in 2012 and 2013. Post assessment in Oregon, Rainier Russet was evaluated in the NWPVDP from 2014 to 2018. During the variety development process, Rainier Russet was evaluated for its agronomy, disease resistance, fresh pack-out, and processing quality potential by researchers at the USDA-ARS, University of Idaho, Oregon State University, Washington State University, and by the National Fry Processor Trials in 2013–2016. The name, Rainier Russet, was selected as a reference to Mount Rainier in Washington State. Rainier Russet was released in 2020 for commercial cultivation due to its improved disease resistance profile, high percentage of uniform, attractive and greater than 170 g U.S. No 1 tubers, high specific gravity, long tuber dormancy, excellent fry color, and low acrylamide forming potential in comparison to the commercial control cultivars Russet Burbank, Ranger Russet, and Russet Norkotah.

Cultivar Description

Plant Characteristics

Foliage (Fig. 2a and d)

Vine maturity is rated as medium- to late-maturing with semi-erect vines exhibiting a medium to large above ground canopy and a lack of wings and anthocyanin coloration in the stems. Foliage is open and leaflets are medium sized

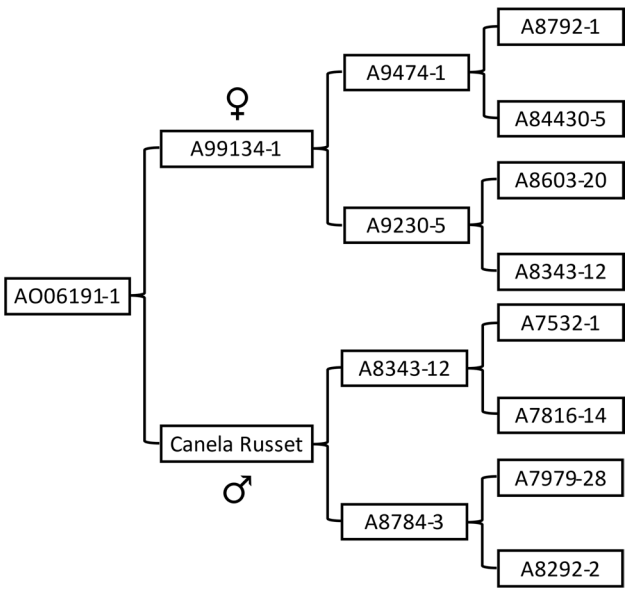

Fig. 1 Pedigree of Rainier Russet (AO06191-1). Rainier Russet resulted from the hybridization between A99134-1 (female) and Canela Russet (AC92009-4RU, male)

with narrowly ovate shape and slight waviness observed on the terminal leaflets with an acuminate tip and acute leaflet base. Leaf color is medium-green (Royal Horticulture Society Color Chart [RHSCC], 137A) and lack anthocyanin coloration on leaf petioles. The number of primary leaflet pairs ranges from 3 to 5 with an average of 4 pairs and the number of secondary and tertiary leaflet pairs ranges from 3 to 5 with an average of 4 pairs.

Flowers (Fig. 2b)

The number of inflorescences per plant ranges from 3 to 8 with an average of 5 inflorescences and each inflorescence averaging 7 florets (4–10 range). The corolla color is all white (RHSCC, 155B) with a rotate shape. Anther color is yellow (RHSCC, 17A) with a narrow cone and some pollen production. Stigma is green (RHSCC, 137A) and capitate in shape. Field conditions are not conducive to berry production though berries may be produced in the greenhouse. Flowers were observed to be both male and female fertile in greenhouse conditions.

Tuber Characteristics

Light Sprouts (Fig. 2c)

Rainier Russet has a long dormancy period (comparable to Russet Burbank) before sprouting occurs. At the base of the sprouts, strong blue-violet anthocyanin pigmentation is observed. Sprouts are conical in shape with a closed habit and very strong pubescence at the tip. When compared to Russet Burbank, Rainier Russet has abundant root initials.

Tubers (Fig. 2e)

Potato tubers are brown (RHSCC, 176A), large, oblong to long (120 mm) with uniform shape, medium thickness (60 mm), and russeted skin. Average mass (281 g) is greater

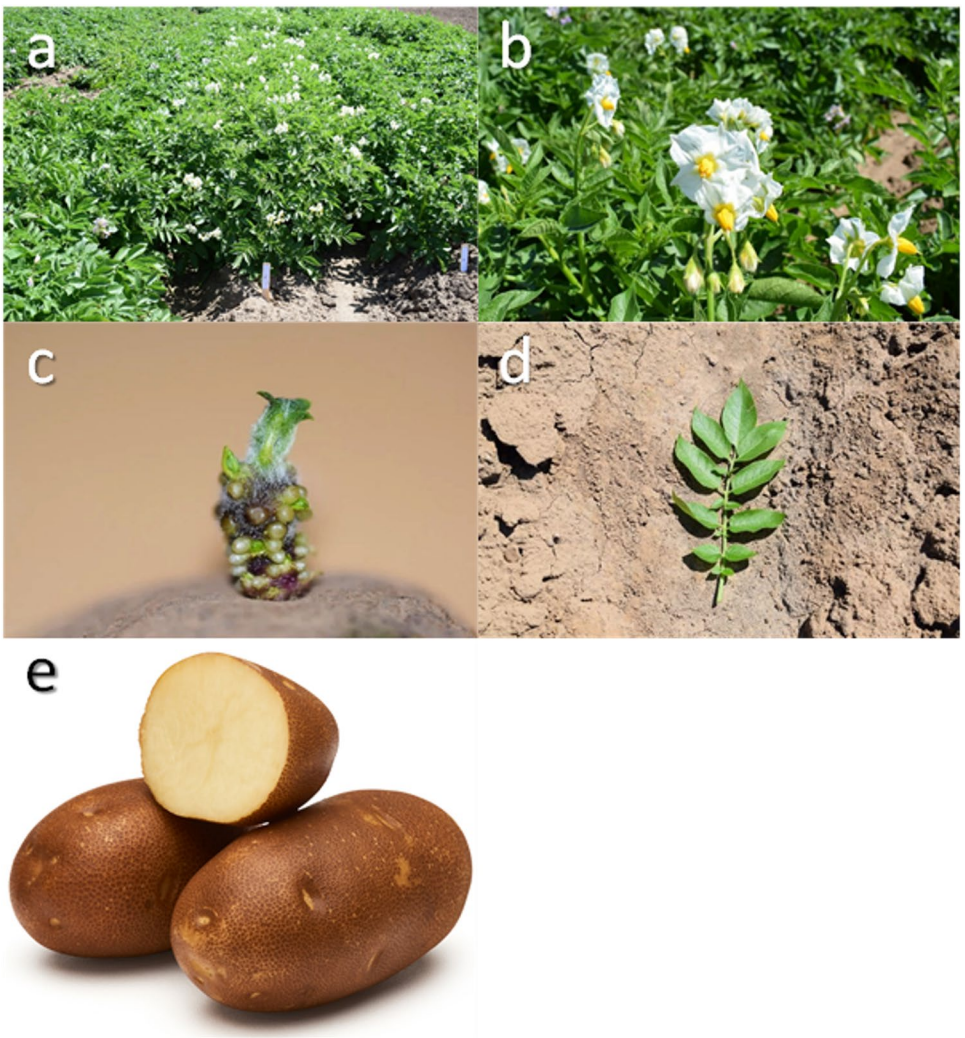

Fig. 2 Rainier Russet's **a**) whole plant, **b**) flowers, **c**) light sprouts, **d**) compound leaf, and **e**) external tuber appearance and tuber flesh color. Photos are courtesy of PVMI

than Russet Burbank (201 g) with Rainier Russet producing a greater percentage of U.S. No.1 yields (89.1% overall). Tuber eyes are shallow, moderate in number (15), and are evenly distributed across the tuber with slight eyebrow prominence. The total number of tubers per plant averages less than 8. Tuber flesh is white (RHSCC, 155B) and tuber dormancy is rated medium to long.

Agronomic Performance and Market Disposition

Rainier Russet has a medium- to late-plant maturity with approximately 120 days to vine senescence after planting. In-field studies from 2014 to 2018 in Othello, WA demonstrated Rainier Russet emerged much later than the controls (Ranger Russet, Russet Burbank, and Russet Norkotah) with an average 2.3% emergence at 30 DAP and 63.8% emergence at 40 DAP when compared to controls, which had an average of 70.1% emergence at 30 DAP and 82.4% emergence at 40 DAP (data not shown). Rainier Russet also produced fewer stems (1.3) than Ranger Russet (2.0), Russet Burbank (2.0), and Russet Norkotah (2.5) (Table 1). Stem number was directly proportional to tuber counts and inversely proportional to average tuber size. The average tuber count for Rainier Russet was 4.9 tubers per plant compared to an average of 7.8 tubers per plant for the controls. Due to the low tuber number per plant and the growth habit of Rainier Russet, the average tuber weight and overall tuber size profile was larger than that of all controls (Table 1). Rainier Russet produced the highest percentage of large (> 340 g) tubers compared to the controls. Sixty one percent of Rainier Russet's tubers were > 340 g compared to Ranger Russet (41%), Russet Burbank (31%), and Russet Norkotah (24%) (Table 1); average tuber weight was 334 g for Rainier Russet compared to 241 g for the controls (data not shown).

The larger tuber size profile of Rainier Russet results in a higher percentage of marketable, fresh tubers in the most valuable size range (~ 240–567 g, USDA Federal-State Market News Service 2023; Spear et al. 2017). Throughout the 5-year study interval in Othello, WA, Rainier Russet produced proportionally more fresh pack carton-sized tubers (carton count) than Russet Burbank, 61% vs 54%, respectively, and was not significantly different from the fresh pack industry standard variety, Russet Norkotah, or Ranger Russet (Table 1). Attractive russet skin and tuber shape ensure Rainier Russet's suitability for the fresh market (Fig. 2.) The improvement in tuber grade and size distribution revealed an improvement in processing market return when compared to Russet Burbank of approximately $120/acre during 2018 (Knowles and Pavek 2018). Conversely, Rainier Russet had a lower process value than Ranger Russet, largely due to low tuber counts and reduced marketable yields (ca. 18% lower marketable yield).

In Oregon statewide trials conducted in 2012 and 2013 at four locations in Oregon, Rainier Russet showed similar total yield when compared with Ranger Russet and Russet Burbank but produced significantly higher yield than Russet Norkotah (Table 2). Further, Rainier Russet produced a higher percent of U.S. No. 1 yield than Russet Norkotah. Rainier Russet produced the largest sized tubers when compared to Russet Burbank and Russet Norkotah (Table 3). In Pacific Northwest early harvest field trials (< 120 days), Rainier Russet total yields were generally lower than those of the controls (Russet Burbank, Ranger Russet, and Russet Norkotah) though its U.S. No. 1 yield was similar to that of the controls when averaged across sites (Table 4). U.S. No. 1 yields for Rainier Russet were higher than Russet Burbank in all three states (ID, OR and WA), higher than Russet Norkotah in Oregon and Washington, and higher than Ranger Russet in Washington (Table 4). The percent U.S. No. 1 yield for Rainier Russet across the three states was 88.6% while the average of the controls was 78.3%.

In late harvest, full-season trials (> 120 days), Rainier Russet total yield exceeded Russet Norkotah in Idaho and Oregon but lagged behind Ranger Russet and Russet Burbank in all three states. Similar to the early harvest trials,

Table 1 Stem and tuber number per plant, carton yield, and tuber size distribution for Rainier Russet and three control varieties

			Carton[1]	Tuber size distribution (categories in grams)			
	Stem No	Tuber No	Yield	0–113	114–227	228–340	> 340
	Per Plant		% of Total Yield2				
Rainier Russet	1.3c	4.9b	61a	3c	13c	23b	61a
Ranger Russet	2.0b	7.7a	58ab	7b	24b	28a	41b
Russet Burbank	2.0b	7.9a	54b	9ab	30ab	30a	31c
Russet Norkotah	2.5a	7.7a	58ab	10a	34a	32a	24d

[1]Carton yield includes U.S. No. 1 grade tubers, 240–567 g

[2]Means averaged across five years (2014–2018) from Washington State University variety trials grown near Othello, WA. The weight of every tuber from each plot, replication, variety, and year was measured by an electronic sizer and the averages calculated. (Pavek, M.J., and N.R. Knowles. 2015–2019. Potato Cultivar Yield and Postharvest Quality Evaluations (crop years 2014–2018). Washington State University Potato Research Group www.potatoes.wsu.edu)

*Letters in each column indicate significant differences LSD ($P < 0.05$)

Table 2 Tuber yields of Rainier Russet as compared to those of Russet Burbank, Ranger Russet, and Russet Norkotah in Oregon statewide trials (2012 and 2013)

Variety	Total yield[1] (MT ha^{-1})	U.S. No. 1 yield[2] (MT ha^{-1})	U.S. No. 1 (%)
Rainier Russet	65a	53a	82ab
Russet Burbank	73a	53a	74b
Ranger Russet	68a	41ab	61c
Russet Norkotah	51b	36b	87a
Mean	64	46	76

[1] Statewide variety trials were conducted at Corvallis, Hermiston, Klamath Falls, and Ontario locations in Oregon

[2] U.S. No. 1 yield considers only tubers greater than 113 g

*Letters in each column indicate significant differences LSD ($P < 0.05$)

Table 3 Summary of tuber specific gravity, harvest French fry color, and average tuber size of Rainier Russet, Russet Burbank, Ranger Russet, and Russet Norkotah conducted in Oregon statewide trials at Corvallis, Hermiston, Klamath Falls and Ontario

Variety	Specific Gravity[1]	Fry color [2]	Fry Color Photovolt[3]	Average tuber wt (g)[4]
Rainier Russet	1.089a	1.4b	41.6a	281a
Ranger Russet	1.089a	1.8ab	37.3b	238ab
Russet Burbank	1.081b	2.2a	32.8d	200b
Russet Norkotah	1.072c	1.8ab	35.5c	198b
Mean	1.083	1.8	36.8	229

[1]Specific gravity was determined using the weight-in-air, weight-in-water method on tuber samples from the 2012-2013 statewide trials

[2]At harvest French fry USDA color chart [0 (lightest)—4 (darkest)]

[3]Photovolt reflectance of at harvest French fries [higher values = lighter fry color]

*Letters in each column indicate significant differences LSD ($P < 0.05$)

U.S. No. 1 yield of Rainier Russet was higher than Russet Burbank and Russet Norkotah in Idaho and Oregon. The percent U.S. No 1 yield in full-season trials for Rainier Russet across states was 91% compared to 78% for the controls (Table 5). Western Regional trials (Table 6) demonstrated similar results to full-season trials with Rainier Russet producing more total yield than Russet Norkotah, similar yield to Russet Burbank, and less yield than Ranger Russet. Rainier Russet also produced higher U.S. No. 1 yields than all controls, except Ranger Russet, though Rainier Russet consistently produced the highest percent U.S. No. 1's (Table 6).

Tuber Quality Characteristics and Usage

Specific Gravity

In Oregon statewide trials, Rainier Russet produced tuber specific gravity values similar to Ranger Russet but higher than Russet Burbank and Russet Norkotah (Table 3). In Western Regional full-season trials from 2015 to 2018, Rainier Russet produced significantly higher specific gravity than the controls, averaging 1.091 compared to the highest control, Ranger Russet, at 1.087 (Table 6).

Processing Characteristics and Storage Management

Post-harvest Evaluations and Processing Attributes

In Oregon statewide trials (2012–2013), Rainier Russet produced lighter fry colors (measured by Photovolt values) when compared to the controls (Table 3). At Washington State University, and as part of the late harvest, full-season Tri-State and Western Regional Potato Variety Development Trials, the post-harvest quality characteristics and processing attributes of Rainier Russet tubers were comparable to Ranger Russet and better than Russet Burbank over the 5-year study period (2014–18). The specific gravity of Rainier Russet tubers was equivalent to Ranger Russet and higher than Russet Burbank in the WA trials, and higher than both standard cultivars in the ID and OR trials (Table 7). When averaged across trial sites, and for tuber portion and severity, the controlled-impact bruising studies described in Table 7 (see footnote c) revealed that Ranger Russet tubers were the most susceptible to bruising (highest percentage) followed by Rainier Russet and Russet Burbank (for differences in tuber portion and severity, see Table 14 and the Tuber Defects section). Rainier Russet tubers displayed greater bruise resistance than Ranger Russet tubers in the ID and OR trials, and similar bruise resistance to Russet Burbank tubers in the Washington and Oregon trials. These trends were consistent across all trial years.

Tubers from the three trial locations were initially stored for 3 months at 8.9 °C (until late December), followed by 4-months at 6.7 °C, and then processed into French fries at the end of April. While all cultivars produced acceptably light-colored fries (≤ USDA 2 color rating) following the 7-month storage period, fries from Rainier Russet tubers were significantly and desirably lighter (avg. Photovolt = 40) than the standard cultivars (avg. Photovolt = 35) in the WA and OR trials (Table 7). However, due to relatively high concentrations of reducing sugars (glucose + fructose) in the stem versus bud ends of tubers, non-uniformity of fry color (stem versus bud end Photovolt difference ≥ 9) was an issue for all cultivars

Table 4 Total yield, U.S. No. 1 yield, and percentage of U.S. No. 1 tubers and tubers > 284 g of Rainier Russet, Ranger Russet, Russet Burbank, and Russet Norkotah in "early-maturing" harvest field trials

Location	Variety	Total Yield	U.S. No. 1 Yield	Percent Yield U.S. No.1	Percent Yield > 284 g
		(MT ha^{-1})	(MT ha^{-1})	(%)	(%)
Idaho[1]	Rainier Russet	40.9	34.8	83	32
	Ranger Russet	46.9	38.6	81	37
	Russet Burbank	47.6	31.6	67	21
	Russet Norkotah	45.5	37.7	82	33
Oregon[2]	Rainier Russet	62.1	55.6	89	60
	Ranger Russet	73.9	56.4	76	39
	Russet Burbank	76.3	55.0	70	22
	Russet Norkotah	66.8	53.2	78	24
Washington[3]	Rainier Russet	53.0	49.6	94	35
	Ranger Russet	52.7	47.6	90	29
	Russet Burbank	56.3	42.3	74	25
	Russet Norkotah	56.5	49.3	87	23

[1] Data from 5 trials conducted from 2014–2018 in Aberdeen, ID

[2] Data from 3 trials conducted from 2016–2018 in Hermiston, OR

[3] Data from 5 trials conducted from 2014–2018 in Othello, WA

Table 5 Total yield, U.S. No. 1 yield and percentages of U.S. No. 1 tubers and tubers > 284 g of Rainier Russet, Ranger Russet, Russet Burbank, and Russet Norkotah in full-season (late-maturing harvest) field trials

Location	Variety	Total Yield	U.S. No. 1 Yield	Percent Yield U.S. No.1	Percent Yield > 284 g
		(MT ha^{-1})	(MT ha^{-1})	(%)	(%)
Idaho[1]	Rainier Russet	54.8	50.4	91	55
	Ranger Russet	65.2	52.5	80	43
	Russet Burbank	61.8	47.3	73	32
	Russet Norkotah	49.4	42.0	84	31
Oregon[2]	Rainier Russet	73.1	64.5	88	59
	Ranger Russet	80.1	59.6	71	37
	Russet Burbank	74.2	45.3	65	17
	Russet Norkotah	50.6	38.9	75	20
Washington[3]	Rainier Russet	73.2	68.2	93	70
	Ranger Russet	90.0	78.6	87	48
	Russet Burbank	83.8	69.3	82	37
	Russet Norkotah	77.2	68.8	89	36

[1] Data from 5 trials conducted from 2014–2018 in Aberdeen, ID

[2] Data from 5 trials conducted from 2014–2018 in Hermiston, OR

[3] Data from 5 trials conducted from 2014–2018 in Othello, WA

at all sites. Only the Washington-grown Rainier Russet tubers had sprouted after 7 months in storage (Table 7). The dormancy of Rainier Russet tubers thus appears comparable to Russet Burbank and much longer than Ranger Russet in the Washington evaluations as compared the Idaho evaluations in which Rainier Russet had a longer dormancy than Russet Burbank (Tables 7 & 8).

Reducing sugars and asparagine are precursors for acrylamide formation during high-temperature processing of French fries. The ability to resist reducing sugar buildup during low temperature storage (cold-sweetening resistance), coupled with inherently low levels of free asparagine, are desirable phenotypes in cultivars being developed for the frozen processing industry (Rosen et al. 2018; Ellis et al. 2020). Tubers of each cultivar were stored for 60 days at 8.9, 6.7, and 4.0 °C to compare susceptibilities to cold sweetening. While Ranger Russet and Rainier Russet tubers sweetened less than Russet Burbank at 6.7 and 4.0 °C, the increases in reducing sugar concentrations (glucose + fructose) with declining storage temperature were substantial

Table 6 Tuber yields and specific gravity of Rainier Russet, Ranger Russet, Russet Burbank, and Russet Norkotah in full-season Western Regional Potato Variety Trials[1]. Values are averages of four year (2015–2018)

Clone	Total yield (MT ha^{-1})	U.S. No.1 yield[2] (MT ha^{-1})	U.S. No. 1 (%)	Specific Gravity[3]
Rainier Russet	58.8b	52.2b	88c	1.091d
Ranger Russet	66.8c	55.2b	82b	1.087c
Russet Burbank	62.8bc	46.5a	72a	1.081b
Russet Norkotah	51.6a	42.5a	81b	1.073a
Mean	60.1	49.1	81	1.083

[1]Western Regional Potato Variety Trials were conducted at 8 locations in California, Colorado, Oregon, Idaho, and Washington

[2]US#1 yield considering only tubers greater than 113-g

[3]Specific gravity data from Western Regional Potato Variety Trials grown in Oregon, Washington, Idaho, Colorado, and California from 2015–2018

[*]Letters in each column indicate significant differences LSD ($P < 0.05$)

(Fig. 3a), reflecting the vulnerability of all three cultivars to cold sweetening (Knowles and Pavek 2018). Rainier Russet tuber asparagine content was significantly lower than Russet Burbank and Ranger Russet at all temperatures (Fig. 3b). Acrylamide forming potential following processing as French fries was specifically assessed as part of the 2013 through 2015 National Fry Processing Trials (NFPT) at the beginning and/or end of the storage seasons. Rainier Russet consistently produced numerically lower asparagine and significantly lower acrylamide levels when compared to Russet Burbank and Ranger Russet, demonstrating positive results to reduce acrylamide in processed potato products (Table 9). Additionally, taste panel scores from 2014 to 2018 showed no difference in taste preference based on growing location, but Rainier Russet had a significantly better taste score (3.46; $p < 0.001$) compared to Ranger Russet (3.28) and Russet Burbank (3.05) when averaged across years and growing locations.

Overall post-harvest merit scores were determined for the cultivars grown at each trial site over the 5-year study period (2014–18). These merit scores are a compilation of ratings for specific gravity, taste panel sensory evaluations of French fries, before-storage and after-storage fry color, and tuber reducing sugar concentrations, as detailed in Table 10 (footnote). A perfect score is 38 (Knowles and Pavek 2018). Rainier Russet and Ranger Russet tubers had comparable post-harvest merit scores that were significantly higher than Russet Burbank tubers in two of three trial locations (Table 10). When averaged over trial sites, the post-harvest merit of Rainier Russet was comparable to Ranger Russet and significantly higher than Russet Burbank.

Full-season storage evaluations to develop commercial recommendations by the University of Idaho, Kimberly Research and Extension Center were completed in 2016–2017. Rainier Russet and Russet Burbank tubers were harvested from trials at Kimberly, Idaho and stored for 268 days at 5.6, 7.2, and 8.9 °C. Sugar content (percent glucose and percent sucrose), fry color, mottling, weight loss, and dormancy duration were assessed. Rainier Russet consistently had a higher percent sucrose than Russet Burbank at all temperatures and throughout the entire storage season (Fig. 4a). Percent glucose was equivalent to or less than Russet Burbank at 7.2 and 8.9 °C but was higher than Russet Burbank after 152 days in storage at 5.6 °C (Fig. 4b). Rainier Russet had similar mottling to Russet Burbank at 5.6 °C, but less mottling at 7.2 and 8.9 °C (Fig. 4c). Rainier Russet produced lighter fry color (measured as higher percent reflectance on fried potato strips) than Russet Burbank throughout the storage season and at all three temperatures, even when percent glucose increased at 152 days (5.6 °C) in Rainier Russet samples (Fig. 4d). Moreover, Rainier Russet fries had significantly fewer sugar ends (5%) when compared to Russet Burbank (45%) in a 9-month storage study averaged over the two-year study (2020–2021) with no differences between temperature treatments. Russet Burbank tubers lost slightly more fresh weight (8.7%) than Rainier Russet (6.0%) at 5.6 °C, and slightly more fresh weight than Rainier Russet (ca. 1.4%) at 7.2 and 8.9 °C (Table 8). The dormancy of Rainier Russet tubers exceeded that of Russet Burbank tubers by approximately 37 days when stored at 7.2 and 8.9 °C (Table 8).

Biochemical, Nutritional and Flavor Characteristics

Rainier Russet, Ranger Russet, Russet Burbank, and Russet Norkotah tubers grown in Aberdeen, ID over a three-year period were analyzed after a six-week storage period at 7.2 °C for biochemical and nutritional composition (Table 11). Dry matter content (percent solids) in Rainier Russet was equivalent to the three control cultivars. Glucose levels were similar to Ranger Russet and Russet Burbank, but significantly lower than Russet Norkotah. Sucrose concentrations were equivalent to Ranger Russet, but significantly higher than Russet Burbank and Russet

Table 7 Post-harvest and French fry processing evaluations of Rainier Russet, Ranger Russet, and Russet Burbank tubers[a]

Cultivar	Specific[b] Gravity	Bruise[c] %	Photovolt Reading[d] Stem	Bud	Avg	Difference[e] Stem vs Bud	USDA Color Rating[f]	% Reducing Sugars[g] Stem	Bud	Avg	Tuber Sprouting[h] % of Tubers	Length (mm)
Washington												
Rainier Russet	1.090a	82ab	36.6	44.8	40.7a[i]	8.6b	0.3	1.0	0.6	0.8	20.3b	4.2
Ranger Russet	1.088a	98a	30.3	41.8	36.0b	11.8ab	0.8	1.4	0.7	1.1	84.0a	17.8
Russet Burbank	1.081b	70b	28.0	43.1	35.5b	15.4a	1.0	1.7	0.6	1.2	5.3b	3.2
Idaho												
Rainier Russet	1.095a	59b	35.2	42.8	39.0a	8.9b	0.7	1.2	0.6	0.9	0.0b	-
Ranger Russet	1.089b	89a	32.3	40.2	36.2a	9.5ab	0.7	1.4	0.7	1.1	51.7a	5.3
Russet Burbank	1.077c	26c	31.4	43.6	37.5a	13.7a	0.7	1.4	0.6	1.0	0.0b	-
Oregon												
Rainier Russet	1.083a	58b	34.1	43.0	38.5a	9.0a	0.5	1.2	0.6	0.9	0.0b	-
Ranger Russet	1.077b	91a	30.0	37.6	33.8b	9.0a	0.5	1.4	0.9	1.2	72.7a	17.8
Russet Burbank	1.073b	71b	28.1	39.5	33.8b	12.9a	1.0	1.7	0.8	1.3	4.0b	0.6

[a]Post-harvest evaluations and ratings were conducted at Pullman, WA in 2014–2017 using tubers from trials at Aberdeen, ID, Hermiston, OR, and Othello, WA. Data for WA and OR are means of four years (2014–17) for fry color and reducing sugars and five years (2014–18) for specific gravity and sprouting. The ID data are averaged over three years (2014–16) for fry color and reducing sugars and four years (2014, 2015, 2016, 2018) for specific gravity and sprouting

[b]Specific gravity of tubers (ca 200–340 g/tuber) was measured within 2–3 weeks of harvest by the weight-in-air/weight-in-water method. Data are averaged over 4 years (n = 48)

[c]Tubers were held under a device that dropped a 113-g weight onto the stem and bud (See Table 14) ends of tubers from a height of 58 cm. Each tuber received four such impacts; two on the stem end and two on the bud end. After 24 h at room temperature, the tubers were peeled and the percentage of impacts resulting in blackspot or shatter bruise calculated. The studies were conducted within 4 weeks of harvest. The data for stem end bruise (4-yr average; n = 48) is presented

[d]French fry planks (0.95 cm × 2.87 cm) from tubers stored for 7 months (3 months at 8.9 °C followed by 4 months at 6.7 °C) 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 f below)

[e]A Photovolt difference of ≥ 9 reflectance units between bud and stem end constitutes non-uniform fry color. Values are the averages of actual Photovolt differences in each of 3 years (n = 36) and therefore do not equate directly to averaged stem and bud values in the table

[f]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 three years

[g]Glucose + Fructose (dry matter basis) were estimated from a polynomial model (see below) that relates fry color to percent reducing sugars assayed by the dinitrophenol method of Ross (1959). Acceptable values for processing are ≤ 2.6%. $RS = 24.338 - 4.3635(PR) + 0.4078X^2 - 0.021758(PR)^3 + 6.833e^{-4}(PR)^4 - 1.2524e^{-5}(PR)^5 + 1.2409e^{-7}(PR)^6 - 5.1353e^{-10}(PR)^7$; n = 1,248; R = 0.87, $P < 0.001$; range of model = 7.6–56.8 Photovolt reflectance units. RS = reducing sugars (% dry matter basis), PR = Photovolt reflectance of French fries (Knowles et al., unpublished)

[h]Average sprout length of tubers showing sprouting (n = 15 tubers were assessed) following 3 months of storage at 8.9 °C

[i]Within a state, means in a column followed by different letters differed significantly (LSD, $P < 0.05$)

Norkotah. Protein composition was equivalent for all four cultivars. Vitamin C content was less than Ranger Russet, a variety known for having high Vitamin C content, and equivalent to Russet Burbank and Russet Norkotah. Total glycoalkaloids for Rainier Russet were significantly higher than the controls, but below the industry accepted threshold of 20 mg 100 g^{-1} tuber fresh weight (Valkonen et al. 1996). A group of chefs analyzed flavor characteristics of Oregon-grown baked Rainier Russet tubers over a period of two years. Rainier Russet has a consistent and pleasing appearance with herbaceous, toast, soil and potato aroma; rich, nutty and earthy taste with creamy, moist, fluffy and smooth texture. Bough et al. (2019) described metabolomic analysis of freeze-dried baked samples of Rainier Russet, Russet Burbank, and Russet Norkotah. The flavor metabolome analysis indicates Rainier Russet is low in pyrazines, similar to Russet Norkotah, with moderate to high terpenes (alpha-copaene) (Table 12). Pyrazines impart an earthy flavor to cooked potatoes while terpenes add herbaceous flavor. Percent amylose of Rainier Russet is similar to that of Russet Burbank (Table 12).

Table 8 Post-harvest evaluation of Rainier Russet and Russet Burbank at the University of Idaho in 2020, 2021, & 2022 from tubers harvest in Kimberly, ID

	Percent Weight Loss[1]			Days to Dormancy Break[2]	
Cultivar	5.6 °C	7.2 °C	8.9 °C	7.2 °C	8.9 °C
Russet Burbank	6.0a	7.5a	7.2a	190a	178a
Rainier Russet	8.7a	8.3a	9.2a	236a	206a

[1]Tubers held for 9-months during the 2020, 2021, and 2022 seasons

[2]Sprout rating scale; 1) no bud activity; 2) sprout initiating but not pointed ("peeping"); 3) sprout pointed with length < 5 mm; 4) sprout elongating with length 5 mm or greater. Dormancy length is then defined as the number of days until 80% of the tubers in the sample rate a 3 or 4 on the sprout rating scale

Tuber Defects

Rainier Russet tubers were less susceptible to growth cracks, second growth, hollow heart/brown center, and internal brown spot than Russet Burbank tubers in Early Tri-State and Western Regional Potato Variety Trials (2015–2018). However, higher levels of hollow heart in Rainier Russet were noted in early trials grown under Washington conditions. Tuber net necrosis and shatter bruise for Rainier Russet were higher than Russet Burbank (Table 13). Rainier Russet black spot bruise expression was similar to Russet Burbank in the field evaluations.

By contrast, post-harvest controlled impact bruise evaluations at Washington State University (2014–2018) and the University of Idaho (2020–2021) showed Rainier Russet to be more susceptible to blackspot bruising than Russet Burbank and but less susceptible than Ranger Russet. WSU evaluations demonstrated Rainier Russet had significantly higher percentage of stem-end bruise incidence (67%) than Russet Burbank (56%), but less than Ranger Russet (93%). The severity of stem-end bruise of Rainier Russet (2.7 rating) was significantly less than that of Ranger Russet (3.8 rating) but was not significantly different than Russet Burbank (2.3 rating; Table 14). More recent evaluations on freshly harvested potatoes from the University of Idaho, Kimberly, Idaho Research and Extension Center demonstrated Rainier Russet had ~ 24% higher incidence of blackspot bruise than Russet Burbank with a greater depth and severity rating at a 18 cm drop height (Table 15). Rainier Russet had 2–6% lower incidence of shatter bruise than Russet Burbank (Table 15).

Responses to Disease and Metribuzin

A composite list of disease evaluations and associated results for Rainier Russet, Russet Burbank, Ranger Russet, and Russet Norkotah conducted over a 3-year study period (2016–2018) at Aberdeen, ID, Hermiston, OR, Corvallis, OR, and Prosser, WA is presented in Table 16. These results demonstrate that Rainier Russet is resistant

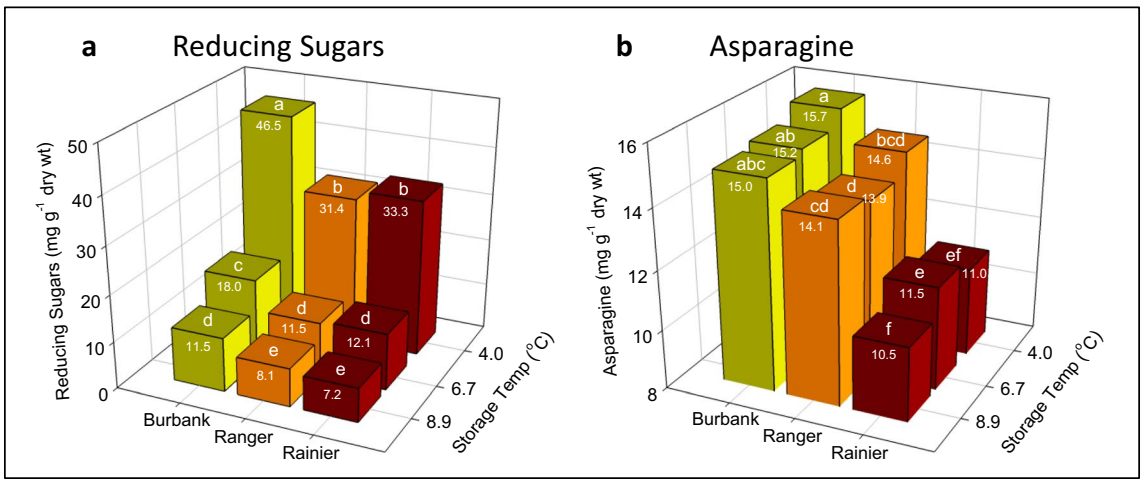

Fig. 3 Reducing sugars **a**) and free asparagine **b**) concentrations in Russet Burbank, Ranger Russet and Rainier Russet tubers after 60 days of storage at 8.9, 6.7 and 4.0 C. Data are averaged over 3 years (2016–18) of Western Regional Trials conducted at Othello, WA. Letters indicate mean separation by LSD ($P < 0.05$). Each bar represents 108 tubers (3 replicates of 12 tubers per season). On a mg g^{-1} dry weight basis, reducing sugar (glucose + fructose) concentrations equate approximately to the following USDA French fry colors: < 13, USDA 0; 14–20, USDA 1; 21–27, USDA 2; 27–37, USDA 3; > 37, USDA 4. Reducing sugars were determined enzymatically as detailed in Ellis et al. (2020). Asparagine was quantified via uv/visible spectrophotometry using the K-ASNAM kit (Megazyme, Bray, Ireland) per the supplier's rapid assay procedure, using extracts prepared as described for glucose and fructose determination (Ellis et al. 2020)

Table 9 Summary of acrylamide levels in Rainier Russet, Russet Burbank, and Ranger Russet. Samples were part of the National Fry Processing Trials (NFPT) from 2013 to 2015. Tubers were stored at 8.3 °C and were analyzed 6 months after storage. 'Early Season' is the growing duration for early-maturing russet potatoes and 'Late Season' is the growing duration for late-maturing russet potatoes by region

	Acrylamide (ppb)					
	2013[1]			2014[2]	2015[2]	
Entry	Asparagine (mg g $^{-1}$ dry weight)	Early Season	Late Season	Early Season	Late Season	Average
Rainier Russet	2.69	820	472	396a	606a	573
Russet Burbank	3.63	2,225	1,008	1,740c	1,174b	1,537
Ranger Russet	-	-	-	988b	1,574b	1,281
Mean	3.16	1,522	740	1,041	1,118	

[1]Rainier Russet when compared to Russet Burbank at two locations in Idaho and North Dakota in 2013 as part of the NFPT

[2]Rainier Russet compared to Russet Burbank and Ranger Russet at four locations in Idaho, North Dakota, Washington, and Wisconsin in 2014 and 2015 as part of the NFPT

*Letters in each column indicate significant differences LSD ($P < 0.05$)

to common scab (*Streptomyces scabies*) and dry rot (*F. solani* var. *coeruleum*), but moderately resistant to foliar early blight (*Alternaria solani*), and metribuzin reaction. Rainier Russet is moderately susceptible or susceptible to verticillium wilt (*Verticillium dahlia* or *albo-atrum*), late blight (*Phytophthora infestans*) foliar infection, late blight (*Phytophthora infestans*) tuber infection, potato virus Y (PVY), dry rot (*Fusarium sambucinum*), soft rot (*Pectobacterium carotovorum* ssp. *carotovorum*; syn. *Erwinia carotovora*), and corky ring spot (tobacco rattle virus; TRV). Generally, Rainier Russet was found to have a better disease resistance package when compared to Ranger Russet, Russet Burbank, and Russet Norkotah in these evaluations.

Table 10 Post-harvest merit scores[a] (maximum = 38) for Rainier Russet, Ranger Russet, and Russet Burbank tubers grown in full-season Tri-State and Western Regional Potato Variety Trials from 2014 through 2018

Cultivar	Washington	Idaho	Oregon	Mean
Rainier Russet	26.6a	26.2ab	27.2a	26.5a
Ranger Russet	25.5a	28.6a	25.3a	26.4a
Russet Burbank	16.6b	20.0b	16.8b	17.8b

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

[a]Merit scores are the sum of individual ratings for fry color from the field and after 60 days storage at 8.9 and 6.7 °C (0 to 5 scale, 0 = darkest to 5 = lightest), reducing sugar concentrations following 60 days storage at 8.9 and 6.7 °C (1 to 5 scale, 1 = highest, 5 = lowest), specific gravity (0 to 5 scale, with ratings of 0 ≤ 1.075; 1 = 1.076 to 1.077 and ≥ 1.096; 2 = 1.078 to 1.079 and 1.094 to 1.095; 3 = 1.080 and 1.092 to 1.093; 4 = 1.081 to 1.082 and 1.089 to 1.091; 5 = 1.083 to 1.088), and average sensory evaluations by taste panelists (1 to 5 scale, 5 = best). With three fry color ratings (field, 8.9, and 6.7 °C), two reducing sugar concentration ratings (8.9 and 6.7 °C), and one rating each for specific gravity and sensory evaluation, a maximum rating of 35 could be obtained if the most favorable score (5) was given in each of the seven total ratings. An additional three points could be added for high fry color uniformity, resulting in a maximum possible post-harvest score of 38 for each cultivar (Pavek and Knowles 2015). Higher scores indicate superior post-harvest attributes. Letters indicate LSD ($P < 0.05$) within a state

Additionally, Fusarium dry rot evaluations were completed by the University of Idaho by dropping tubers of Russet Burbank and Rainier Russet through a potato wounding box (Schisler et al. 2000) and inoculated by spraying (50/50 thiabendazole sensitive to resistant mixture) *Fusarium sambucinum* on the tuber surface. Tubers were then placed at 12.8 ºC (95% RH) and the temperature decreased by 0.28 ºC day^{-1} until reaching the final storage temperature of 7.2 ºC and stored for approximately 98 days. Rainier Russet had significantly less Fusarium dry rot decay (11.6%) and lower percent incidence (39.3%) of potatoes with greater than 5% decay compared to Russet Burbank (38.7% and 74.8%) in a two-year bruised and inoculated study (Table 17). These data corroborate the resistance to Fusarium dry rot reported for Rainier Russet in Table 16.

Cultural Management Recommendations

Idaho Production

Results from several management studies in southern Idaho may provide the potato industry, nationally and internationally, with management guidelines for Rainier Russet potatoes.

The ideal seed size for Rainier Russet is between 57 and 85 g with a final planting depth of 20 cm from the top of the seed piece to the top of the hill. Potato seed should

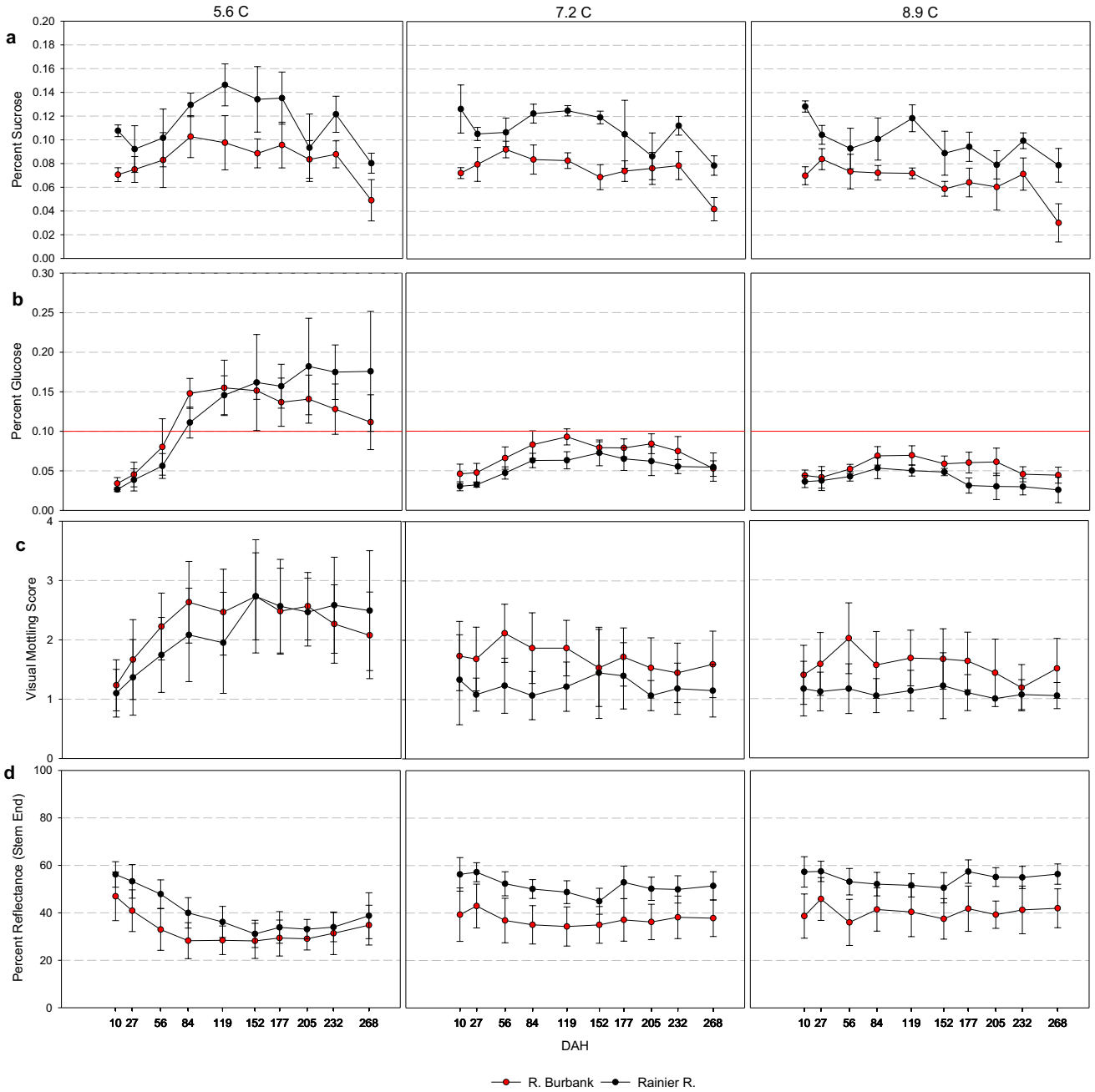

Fig. 4 Tuber percent sucrose (a), percent glucose (b), visual mottling score (c), and percent reflectance (fry color; d) of Rainier Russet and Russet Burbank over 7-months in storage during 2016–2017 at 5.6, 7.2, and 8.9 °C; tubers were from research plots grown at Kimberly, ID. These three storage temperatures 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. Red line in (b) indicates upper for acceptable level of glucose. Fry colors with Photovolt light reflectance readings of ≥ 35 are acceptable in this study. Standard error bars are represented in each graph. Visual mottling was rated using the University of Idaho's mottling assessment protocol. 1) no mottling, 2) mild mottling on one end of the fry plank, 3) mild mottling throughout the plank, and 4) severe mottling throughout the plank

be planted when the soil temperature is between 7.2 and 12.8 °C to minimize disease infections common in cool soils. While Rainier Russet is resistant to *Fusarium solani* var. *coeruleum*, it is moderately susceptible to *Fusarium sambucinum* and should be treated with an appropriate fungicide as needed.

Rainier Russet has shown moderate resistance to metribuzin when applied at labeled rates (Table 16). Soils with a

Table 11 Biochemical composition[1] of Rainier Russet, Ranger Russet, Russet Burbank, and Russet Norkotah tubers. Data is averaged from Aberdeen, Idaho and Texas trials

Component	Rainier Russet	Ranger Russet	Russet Burbank	Russet Norkotah	$LSD_{0.05}$
Solids (%)[2]	23.4	22.3	20.4	19.9	ns [7]
Glucose (% FWB)[3]	0.046a	0.059ab	0.044a	0.072b	0.022
Sucrose (% FWB)[3]	0.192b	0.189b	0.138a	0.115a	0.045
Protein (% DWB)[4]	5.59	5.23	5.04	4.94	ns [7]
Vitamin C (mg 100 g^{-1})[5]	22.0a	30.5b	23.5a	21.7a	5.0
Glycoalkaloids (mg 100 g^{-1})[6]	9.3b	3.7a	2.5a	2.1a	2.2

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

[2]FWB = Fresh Weight Basis; DWB = Dry Weight Basis

[3]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 45,387

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

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

[6]Total glycoalkaloids determined by Bergers' protocol (1980)

[7] ns – Not significant at 0.05 probability level

Table 12 Levels of flavor-associated compounds of Rainier Russet, Russet Burbank and Russet Norkotah: Data obtained from freeze dried baked tuber samples grown at Hermiston, Oregon in 2019. Standard deviation is in parenthesis for each observation

	Rainier Russet	Russet Burbank	Russet Norkotah
*Pyrazines**			
2,3,5-trimethyl-6-butylpyrazine	472 (±27)	3,672 (±1125)	419 (±58)
2,3-diethyl-5-methylpyrazine	1,376 (±76)	9,674 (±3,564)	1,931 (±166)
2-isobutyl-3-methylpyrazine	443 (±36)	5,123 (±3,745)	523 (±76)
*Terpenes**			
Alpha-Copaene	11,110 (±6,649)	1,638 (±128)	5,774 (±3,371)
Starch			
% Amylose	0.41	0.42	NA

*Peak areas

Table 13 Internal and external tuber defect ratings for Rainier Russet and Russet Burbank

Defects[1]	Rainier Russet	Russet Burbank
Growth cracks[2]	4.8	4.2
Second growth[2]	4.7	3.4
Shatter bruise[2]	3.8	4.6
Blackspot bruise[3], %	4.1	3.9
Hollow heart/Brown center[3], %	2.2	6.6
Internal brown spot[3], %	0.0	3.1
Net necrosis[3], %	2.8	1.7

[1]Defect data taken from the Early-Maturing Tri-State and the Early-Maturing Western Regional Potato Variety Trials conducted in 2015–2018

[2]1 – 5 scale where 1 = severe occurrence of the defect and 5 = no occurrence of the defect

[3]Percent of tubers > 284-g with the defect

history of early die and/or nematodes may benefit from fumigation for tuber production. Additionally, fungicide programs should be used to prevent early and late blight infections.

Early-Harvest Production

In-row spacing for early-harvest production [100 to 110 days after planting (DAP)] destined for the processing market should be 25 to 30 cm when planted into rows spaced 91 cm apart and in-row spacing should be decreased to 23 to 25 cm for fresh pack production.

Nitrogen fertilization trials conducted at Aberdeen, ID indicate that cost-adjusted gross return for Rainier Russet was maximized at seasonal nitrogen rates of 175 to 195 kg N ha^{-1} (soil N plus fertilizer) compared to 195 to 205 kg N ha^{-1} for Russet Burbank. Around 100 to 115 kg N ha^{-1} should be available at tuber initiation (about 60 DAP) with the remainder applied via sprinkler

Table 14 Washington State University controlled impact bruise assessment results from the Tri-State and Western Regional Potato Variety Trials from 2014 to 2018. Potatoes were grown in Othello, WA, Aberdeen, ID, or Hermiston, OR and transferred to Pullman, WA for analysis

		Black Spot Bruise Potential											
		Rainier Russet				Ranger Russet				Russet Burbank			
		Percent		Color (5 = darkest)		Percent		Color (5 = darkest)		Percent		Color (5 = darkest)	
		Stem	Bud	Stem	Bud	Stem	Bud	Stem	Bud	Stem	Bud	Stem	Bud
2014	Washington	83	13	3.0	1.3	96	50	4.3	2.1	75	25	3.0	1.5
	Idaho	63	8	2.3	1.2	79	25	3.3	1.6	13	4	1.3	1.1
	Oregon	42	13	2.0	1.3	96	13	4.2	1.3	71	17	2.8	1.3
2015	Washington	92	4	3.5	1.1	96	13	4.0	1.3	21	4	1.5	1.1
	Idaho	46	0	2.0	1.0	88	13	3.5	1.3	33	4	1.7	1.1
	Oregon	79	13	3.1	1.3	92	0	3.9	1.0	71	4	2.9	1.1
2016	Washington	83	8	3.1	1.2	100	38	4.5	1.8	83	8	3.6	1.2
	Idaho	71	0	2.7	1.0	100	4	4.2	1.1	46	0	2.0	1.0
	Oregon	38	0	1.9	1.0	92	29	3.9	1.6	75	0	3.0	1.0
2017	Washington	96	75	3.8	2.8	100	29	4.4	1.6	92	17	3.6	1.4
	Idaho	-	-	-	-	-	-	-	-	25	4	1.7	1.1
	Oregon	67	13	2.7	1.2	79	4	3.3	1.1	63	4	2.5	1.1
2018	Washington	58	4	2.4	1.1	100	38	4.6	1.8	79	17	3.0	1.3
	Idaho	54	0	2.3	1.0	88	0	3.5	1.0	13	0	1.3	1.0
	Oregon	63	29	2.5	1.6	96	13	1.3	1.3	75	8	1.3	1.3
	3-State Ave	67	13	2.7	1.3	93	19	3.8	1.4	56	8	2.3	1.2
	WA Ave	82	21	3.2	1.5	98	34	4.4	1.7	70	14	2.9	1.3
	ID Ave	59	2	2.3	1.1	89	11	3.6	1.3	26	2	1.6	1.1
	OR Ave	58	14	2.4	1.3	91	12	3.3	1.3	71	7	2.5	1.2
	$LSD_{(0.05)}$	18	ns	ns	ns	18	ns	ns	ns	18	ns	ns	ns

Impact bruise evaluations are assessed by warming tubers to room temperature for 24 h before dropping a 113-g weight from a height of 58.5-cm on both the stem and bud end. Tubers are held for 24 h at room temperature before peeling and scoring bruise

Bruise severity rating: 1 = No bruise; 2 = White knot bruise; 3 = Less than 50% of the impact area darkened; 4 = Greater than 50% of the impact area darkened, or the whole impact area is light brown; 5 = 100% of the impact area is dark

$LSD_{(0.05)}$ is reported for the interaction of year x cultivar

irrigation throughout the season finishing by the last week of July. Additional nitrogen response data also suggest that petiole levels for Rainier Russet be around 14,000 ppm at the end of tuber initiation (60 DAP), decreased to 9,000 to 11,000 ppm during early bulking (80 to 90 DAP), and around 6,000 ppm during late bulking (100 to 110 DAP).

Late-Harvest (Full-Season) Production

In-row spacing for late-harvest production (> 120 DAP) for either fresh or processing should be 25 to 30 cm when planted into rows spaced 91 cm apart. Nitrogen fertilizer trial data showed that the cost adjusted gross return was maximized at seasonal nitrogen rates between 180 and 200 kg N ha^{-1} compared to 230 to 250 kg N ha^{-1} for Russet Burbank. Petiole nitrate levels should be around 17,500 ppm at the end of tuber initiation (60 DAP) decreasing to 13,000 to 14,000 ppm during early bulking (80 to 90 DAP) and 9,000 ppm during late bulking (around 110 DAP). Overall, Rainier Russet requires 10 to 20% less nitrogen than Russet Burbank. Nitrogen applications should be completed 30 days prior to harvest to ensure adequate skin set. These data should help provide a starting point for establishing nutrient requirements for Rainier Russet in other growing regions.

Phosphorus, potassium, and micronutrient requirements have not been established for Rainier Russet. Until this data is available, it is recommended that growers follow local nutrient management recommendations for Russet Burbank (Stark et al. 2004) until new guidelines for Rainier Russet become available.

Table 15 Blackspot bruise incidence, severity, depth, and shatter bruise incidence for tubers impacted at an 18-cm drop height combined for 2020 and 2021 and a 30-cm drop height in 2021. Values within a column followed by the same letter were not significantly different ($\alpha < 0.05$)

Cultivar	Blackspot bruise incidence (%)	Blackspot bruise severity rating (1–4)	Blackspot bruise depth (mm)	Shatter bruise incidence (%)
18-cm				
Rainier Russet	81b	2.5b	4.4b	2a
Russet Burbank	57a	1.9a	2.8a	4a
30-cm				
Rainier Russet	91a	2.8b	5.1b	17a
Russet Burbank	78a	2.1a	4.0a	23a

Blackspot bruise severity was evaluated by dropping 100-g weight from a height of 18- and 30-cm on both the apical and basal end of 3 replicates of 5 clean potato tubers (170–300 g) with a pulp temperature of 12.8 °C. Tubers were then held for 24 h at 21.1 °C before scoring visually

Evaluation of color formation severity was assessed following the protocol of Hendricks et. al. 2021 and numbers were represented on a 1–4 scale (1 = no color, 2 = light gray color, not severe but discoloration occurred, 3 = dark gray color, severity was moderate, dark but not extreme, 4 = dark gray/black color, severity was extreme)

*Letters in each column indicate significant differences LSD ($P < 0.05$)

Columbia Basin of Washington and Oregon

Rainier Russet typically produces a larger tuber size profile than Ranger Russet, Russet Burbank, and Russet Norkotah. Rainier Russet tends to produce fewer tubers per plant (4.8 vs. 7.8) than the same three varieties listed above. Recommended seed-piece depth is 18–20 cm from top of hill to top of seed piece, after all post-planting tillage is finished. Similar to most varieties grown in the Columbia Basin, Rainier Russet will produce up to 6% more net revenue when planted into 81 cm rows versus 86 cm rows.

Early-Harvest Production

Rainier Russet is typically a medium-maturing variety when grown in the Columbia Basin of WA and OR (< 120 days after planting). It can be grown for an early-to mid-season harvest, especially if the vines are removed prior to natural maturity. For an early- to mid-season harvest between mid-July and mid-August, (100–120 days after planting (DAP)), seed pieces should be spaced approximately 20–25 cm apart in-row. Total seasonal N applications should be 280–315 kg ha^{-1}, including pre-plant and residual inorganic soil N (NO_3-N plus NH_4-N).

Late-Harvest (Full-Season) Production

For full season growth with a harvest between mid-August and October (> 130 DAP), seed should be spaced 20–25 cm apart in-row. Total seasonal N applications should be 335–365 kg ha^{-1} for fresh-market and 365–390 kg ha^{-1} for process market, including pre-plant and residual inorganic soil N (NO_3-N plus NH_4-N). We recommend applying pre-plant or at-planting nitrogen so there is 140–170 kg ha^{-1} of available N (soil residual N + applied) in the root zone at emergence. Petiole and soils during the growing season should be used as a guide, however, growers should strive to hit the season total N targets. Typical petiole nitrate (NO_3-N) concentrations for Rainier Russet on June 15 = 23,000 ppm, July 1 = 20,000 ppm, July 15 = 19,000 ppm, and July 30 = 15,000 ppm. Petiole values alone should not drive in-season nutrient applications. Soil N should be at or below 55 kg ha^{-1} by mid-July and plants kept healthy via "spoon-feeding" of nitrogen. With low soil N and the cessation of N applications prior to August, plants will be able to adequately mature during August and into September. Full season rates do not account for N applications to aid in crop residue breakdown.

The petiole phosphorus data was 0.33–0.55% during tuber initiation, steadily decreased to 0.26–0.30% during tuber setting and 0.10–0.15% during the end of tuber bulking stage. Petiole potassium sufficiency ranges for Rainier Russet are 9.8–11.3% during tuber initiation, 8.7–9.4% during tuber set, and 8.6% during the end of bulking stage. A preliminary trial showed that the phosphorus fertilizer did not improve potato yield at soil P levels of 27 ppm; however, up to 280 kg ha^{-1} P_2O_5 P should be added to soil when soil levels are at or below 20 ppm. Based on existing data for the main cultivars in the Columbia Basin, potassium fertilization did not improve potato yield at soil available K levels of 170 ppm; this level may be suitable for Rainier Russet. Future, specific fertility recommendations will be developed with more data. Micronutrient requirements have not been established for Rainier Russet, therefore, it is recommended that growers follow local nutrient management recommendations (Lang et al. 1999) for Russet Burbank until new guidelines for Rainier Russet become available.

Table 16 Disease reactions and metribuzin response of Rainier Russet and control varieties in trials conducted in Western Regional trials (2016–2018)

Disease[1]	Rainier Russet	Russet Burbank	Ranger Russet	Russet Norkotah
Verticillium wilt (*Verticillium*)	S	S	MS	VS
Common scab (*Streptomyces*)	R	R	S	S
Foliar early blight (*Alternaria*)	MR	MS	MS	S
Late blight (*Phytophthora infestans*) foliar infection	S	S	S	S
Late blight tuber infection	S	S	S	S
PVY	S	S	S	S
Dry rot (*Fusarium sambucinum*)	MS	S	MR	MS
Dry rot (*F. solani* var. *coeruleum*)	R	MS	MR	MR
Soft rot (*Pectobacterium*)	S	MS	MR	S
Corky ring spot (TRV)	S	S	S	S
Metribuzin reaction	MR	R	R	MR

[1]Ratings of Rainier Russet response to diseases were based on a minimum of 3 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). Verticillium wilt was evaluated at Aberdeen, ID and Hermiston, OR; corky ringspot and potato mop top virus were evaluated at Prosser, WA; common scab was evaluated at Aberdeen, ID; early blight, *Pectobacterium* (syn. *Erwinia*) soft rot, Fusarium dry rot were evaluated at Aberdeen, ID; PVY evaluations were performed at Hermiston, OR; and late blight was evaluated at Corvallis, OR

Table 17 Percent decay and percent incidence of potatoes with greater than 5% decay of Fusarium dry rot in bruised and inoculated lots of Russet Burbank and Rainier Russet potatoes stored at 7.2 ℃. Values are means of two years (2020–2021). Mean values followed by the same letter are not significantly different from one another ($p < 0.05$) based on Fisher's protected LSD

Cultivar	Percent Decay	Percent Incidence (Potatoes with > 5% decay)
Russet Burbank	38.7 a	74.8 a
Rainier Russet	11.6 b	39.3 b

Irrigation Management

Available soil moisture (ASM) should be maintained as close to 85% as possible without dropping below 65% from full emergence until late bulking. Throughout the season, irrigation applications equivalent to the evapotranspiration loss should be applied to maintain soil near 85% ASM (Gonzalez et al. 2023). Plant water uptake decreases markedly in late August as vines senesce. During the last 3 weeks of growth and as vines senesce, ASM should be reduced to about 60–65%. Avoid excessive soil moisture from mid to late bulking to prevent disease, rot, and shatter bruising at harvest. Approaching harvest, irrigation application rates should be adjusted to maintain ASM at 60 to 70% to avoid excessively wet soil conditions, and the promotion of disease and enlarged lenticels. Low soil moisture conditions (below 60% ASM) should be avoided during tuber maturation and harvest to minimize tuber weight loss and blackspot bruise.

Vine Kill and Harvest

Similar to many potato varieties, Rainier Russet is susceptible to shatter and blackspot bruising at harvest. Shatter, mechanical cracking, thumbnail cracks, and air checks are terms that refer to hairline fractures in the tuber that typically result when turgid tubers collide with a solid surface. Turgid tubers (firm, well hydrated, high fluid content) are more susceptible to shatter bruise than flaccid tubers. Irrigation should be gradually reduced during the last two weeks prior to vine kill to decrease tuber hydration to an intermediate level during skin set. Vine kill two to three weeks before harvest to improve skin set and harvest at pulp temperatures below 15 °C to reduce storage disease potential. Avoid leaving tubers too long under dead vines which may lead to overly mature tubers and subsequent storage problems. Handle tubers gently to minimize tuber bruise damage, which may provide entry points for disease in storage. Facilitate Fusarium dry rot control for tubers in storage by minimizing tuber skinning and bruising during harvest and subsequent handling.

Genotyping

A selected set of 14 Simple Sequence Repeat (SSRs) markers, as identified by Bali et al. 2017, were used for DNA fingerprinting purposes and PVP (Plant Variety Protection) of Rainier Russet. The 14 SSR markers separated Rainier Russet from Russet Burbank as indicated with allele sizes for each SSR marker (Table 18). Rainier Russet was issued PVP on April 14, 2023 (#20210042).

Table 18 DNA Fingerprints of Rainier Russet, and Russet Burbank with 14 selected SSR markers

SSR Name	Rainier Russet	Russet Burbank
STI0033	109/115/128	109/128
STM1104	164/167/170	164/167/170/173
STM1016	246/258	243/258
STM0030	138/162	138/156/162
STG0016	132/135	135/153
STM5140	176	182/188
STI0019	119	105/109/115
STG0004	192/194/196	192/194/196
STI0030	82/88/103	82/88/103
STG0010	162	159/166
STM1052	225	225
STI0038	95/101	95/101
STM1064	187/193	187/190
STGBSS	124/128/132	128
STM1053	170	168/170
STG0001	127	125
STI0012	170/182	170/182
STM5127	241/248	238/248
STI0014	118/125/128	125/128

Seed availability

Disease-free pre-nuclear plantlets and mini-tubers are available from Shannon Kuhl, the director of the Nuclear Seed Potato Program, at the University of Idaho Tissue Culture Laboratory, Moscow, ID. Certified seed is available from potato seed growers in Colorado, USA; Montana, USA; North Dakota, USA; and Alberta, Canada. Grower contact information is posted on the Potato Variety Management Institute (PVMI) website (PVMI.org). Based on an agreement between associated research universities, the Northwest Potato Variety Development Program (NWPVDP) and PVMI, Rainier Russet was licensed to PVMI. PVMI is a non-profit organization working on behalf of the NWPVDP Program.

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Declarations

Conflict of Interest The authors declare no conflict of interest.

All experiments within this study comply with current laws within the United States of America in which they were conducted.

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